S. HRG. 104-181

HEARING ON THE NASA SPACE STATION PROGRAM

HEARING

BEFORE THE

SUBCOMMITTEE ON SCIENCE, TECHNOLOGY, AND SPACE

OF THE

COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION UNITED STATES SENATE

ONE HUNDRED FOURTH CONGRESS

FIRST SESSION

MAY 23, 1995

Printed for the use of the Committee on Commerce, Science, and Transportation

U.S. GOVERNMENT PRINTING OFFICE

91-113 CC WASHINGTON : 1995

For sale by the U.S. Government Printing Office
Superintendent of Documents, Congressional Sales Office, Washington, DC 20402
ISBN 0-16-047727-1

S. HRG. 104-181

HEARING ON THE NASA SPACE STATION PROGRAM

HEARING

BEFORE THE

SUBCOMMITTEE ON SCIENCE, TECHNOLOGY, AND SPACE

OF THE

COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION UNITED STATES SENATE

ONE HUNDRED FOURTH CONGRESS

FIRST SESSION

MAY 23, 1995

Printed for the use of the Committee on Commerce, Science, and Transportation

U.S. GOVERNMENT PRINTING OFFICE

91-113 CC WASHINGTON : 1995

For sale by the U.S. Government Printing Office
Superintendent of Documents, Congressional Sales Office, Washington, DC 20402
ISBN 0-16-047727-1

COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION

LARRY PRESSLER, South Dakota, *Chairman*

BOB PACKWOOD, Oregon	ERNEST F. HOLLINGS, South Carolina
TED STEVENS, Alaska	DANIEL K. INOUYE, Hawaii
JOHN McCAIN, Arizona	WENDELL H. FORD, Kentucky
CONRAD BURNS, Montana	J. JAMES EXON, Nebraska
SLADE GORTON, Washington	JOHN D. ROCKEFELLER IV, West Virginia
TRENT LOTT, Mississippi	JOHN F. KERRY, Massachusetts
KAY BAILEY HUTCHISON, Texas	JOHN B. BREAUX, Louisiana
OLYMPIA J. SNOWE, Maine	RICHARD H. BRYAN, Nevada
JOHN ASHCROFT, Missouri	BYRON L. DORGAN, North Dakota

PATRIC G. LINK, *Chief of Staff*
KEVIN G. CURTIN, *Democratic Chief Counsel and Staff Director*

SUBCOMMITTEE ON SCIENCE, TECHNOLOGY, AND SPACE

CONRAD BURNS, Montana, *Chairman*

LARRY PRESSLER, South Dakota	JOHN D. ROCKEFELLER IV, West Virginia
KAY BAILEY HUTCHISON, Texas	JOHN F. KERRY, Massachusetts
TED STEVENS, Alaska	RICHARD H. BRYAN, Nevada
TRENT LOTT, Mississippi	BYRON L. DORGAN, North Dakota

CONTENTS

LIST OF WITNESSES

APPENDIX

HEARING ON THE NASA SPACE STATION PROGRAM

TUESDAY, MAY 23, 1995

U.S. SENATE,
SUBCOMMITTEE ON SCIENCE, TECHNOLOGY, AND SPACE,
COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION,
Washington, DC.

The subcommittee met, pursuant to notice, at 9:32 a.m., in room SR–253, Russell Senate Office Building, Hon. Conrad Burns (chairman of the subcommittee) presiding.

Staff members assigned to this hearing: Louis C. Whitsett, staff counsel, and Timothy B. Kyger, professional staff member; and Patrick H. Windham, minority senior professional staff.

OPENING STATEMENT OF SENATOR BURNS

Senator BURNS. The subcommittee on Science, and Technology and Space will come to order.

This morning, we are examining the $30 billion International Space Station program, the largest, most expensive space mission that has ever been undertaken by this government or anybody else.

Let me start out by saying this morning, let me apologize for being a couple minutes late here. I like to keep these things on time because you have a busy day, and of course it is a little bit busy up here in this little area that we call of logic-free environment that we operate here.

Let me start out by saying that I support the Space Station. I believe the Space Station is a unique opportunity for our space faring nations to combine their resources, their talent, their imagination, to produce a giant orbital laboratory to benefit the entire world community.

Space Station should give us information about long duration human space flight that will be crucial to any next generation missions to the moon or maybe even to the planets and then beyond.

In addition, Space Station will allow researchers to do microgravity research that cannot be performed on Earth. This research could well lead to dramatic breakthroughs in biomedicine, advanced materials that enhance the quality of life and boost the U.S. competitiveness here on this planet.

While the commercial spinoffs from space missions can sometimes be overstated, it has been estimated that, for every dollar invested in the space program, the U.S. has received $8 in return in the form of commercial products and new technologies.

Communication satellites, micro-electronics, advanced water filtration systems and many other things that have been taken for granted have all had their origins in space.

I fully recognize that we are in a tough budget environment. Every time you pick up the newspaper, everybody understands that. First of all, NASA is looking to cut $5 billion in 5 years from its budget. Beyond that, the House and Senate budget plans call for even deeper cuts as Congress attempts to balance the Federal budget by the year 2002.

These difficult circumstances will force Congress to make some tough choices from among many of equally deserving programs. However, in making those choices, I believe that the Space Station program is a must for a national priority.

In recent years, Space Station has come to be viewed as strictly a U.S. program, whose funding cancellation would only affect our country. However, the Space Station is an international effort.

Already, Western Europe, Japan, Canada and our other Station partners have invested a total of $5 billion with plans to spend $4 billion more.

If the U.S. were to cancel Space Station after such a massive investment by our foreign partners, our credibility could be seriously damaged.

More specifically, the U.S. might find it difficult to seek out international partners for any future big science projects, which have become too complex and too expensive for any one nation to fund or to manage by itself.

While I support Space Station, there are some aspects of the current program that concern me. First, there is the matter of the Russian participation. When the Russians were added as partners in 1993, we welcomed their decades of experience in building Space Stations.

Equally important, the Russian participation was said to reduce our costs by $2 billion and advance the assembly schedule by 1 year.

However, in view of many observers, the current Space Station may suffer from an overreliance on the Russians for both Space Station hardware and launches. For example, many critical Station elements, like the navigation system and the crew rescue vehicles, are to be supplied by the Russians.

In addition, over 40 of the 73 missions to assemble and service the Station will involve the launch of Russian rockets from Russia. If the Russians are able to follow through on their obligations, there may be no need to worry.

However, concerns about the health of the Russian space industry, the condition of their launch infrastructure, and Russians, recent dealings with nations unfriendly to the U.S., have caused many to reexamine the Russian element of the Space Station program.

At today's hearing, I hope we will have time to examine the Russian component of the Space Station plan. One of the current plans is too dependent upon the Russians.

We also welcome testimony on any NASA contingency plans for the possibility of non-participation by the Russians.

In addition, I hope to have time to address the troubling reports that the European Space Agency and Canada may be reassessing their future involvement with the program. It would be disappointing if that were true. Hopefully, our witnesses will shed some light on that situation this morning.

I am going to put the rest of my statement in the record.

[The prepared statement of Senator Burns follows:]

PREPARED STATEMENT OF SENATOR BURNS

This hearing will now come to order. Today the Science Subcommittee will examine the $30-billion International Space Station program, the largest and most expensive space mission ever undertaken.

Let me start by saying that I support Space Station. I believe that Space Station is a unique opportunity for our space faring nations to combine their resources, talent, and imagination to produce a giant orbital laboratory to benefit the entire world community. Space Station should give us information about long duration human space flight that will be crucial to any next-generation missions to the moon or Mars. In addition, Space Station will allow researchers to do microgravity research that cannot be performed on Earth. This research could well lead to dramatic breakthroughs in biomedicine and advanced materials that will enhance our quality of life and boost U.S. competitiveness.

While the commercial spinoffs from space missions can sometimes be overstated, it has been estimated that, for every dollar invested in the space program, the U.S. has received eight dollars in return in the form of commercial products and new technologies. Communications satellites, microelectronics, advanced water filtration systems, and many other things that we take for granted all have their origins in the space program.

I fully recognize that we are in a tough budget environment. First of all, NASA is looking to cut $5 billion in five years from its budget. Beyond that, the House and Senate budget plans call for even deeper cuts as the Congress attempts to balance the federal budget by the year 2002. These difficult circumstances will force Congress to make some tough choices from among many equally deserving programs. However, in making those choices, I believe that the Space Station program must be a national priority.

In recent years, Space Station has come to be viewed as strictly a U.S. program, whose funding or cancellation would only affect our country. However, Space Station is an international effort. Already, Western Europe, Japan, Canada, and our other Station partners have invested a total of $5 billion, with plans to spend $4 billion more. If the U.S. were to cancel Space Station after such a massive investment by our foreign partners U.S. credibility could be seriously damaged. More specifically, the U.S. might find it difficult to seek out international partners for any future "big science" projects, which have become too complex and too expensive for any one nation to fund and manage by itself.

While I support Space Station, there are some aspects of the current program that concern me. First, there is the matter of Russian participation. When the Russians were added as partners in 1993, we welcomed their decades of experience in building Space Stations. Equally important, the Russian participation was said to reduce Station costs by $2 billion and advance the assembly schedule by one year.

However, in the view of many observers, the current Space Station may suffer from an **overreliance** on the Russians for both Station hardware and launches. For example, many critical Station elements like the navigation system and the crew rescue vehicles are to be supplied by the Russians. In addition, over forty (40) of the seventy-three (73) missions to assemble and service the Space Station will involve the launch of Russian rockets from Russia.

If the Russians are able to follow through on their obligations, there may be no need to worry. However, concerns about the health of the Russian space industry, the condition of their launch infrastructure, and Russia's recent dealings with nations unfriendly to the U.S. have caused many to reexamine the Russian element of the Space Station program. At today's hearing, I hope we will have time to examine the Russian component of the Space Station plan and whether the current plan is too dependent on the Russians. We also welcome testimony on any NASA contingency plans for the possibility of non-participation by the Russians.

In addition, I hope to have time to address the troubling reports that the European Space Agency and Canada may be reassessing their future involvement with

the program. It would be disappointing if that were true. Hopefully, our witnesses will shed some light on that situation this morning.

Another concern is the amount of spacewalking required of our astronauts under the current Space Station plan. In February of this year, NASA estimated it will take 645 hours of spacewalking to construct the Space Station. By comparison, U.S. astronauts accumulated a total of about 600 hours of spacewalking from 1965 to 1994. Since excessive spacewalking places the crew at risk and adds to the inherent complexity of the construction task, this issue deserves close scrutiny by this Subcommittee.

Finally, the Subcommittee will examine the scientific merit of the Space Station. Critics have raised doubts about whether any good science can be conducted on the Space Station. Furthermore, the GAO has raised questions about whether enough attention is being given to the ground-based research that would supposedly rely on the Space Station.

Again, let me welcome our distinguished group of witnesses to the Subcommittee.

Senator BURNS. I welcome this morning the chairman of the full committee, Larry Pressler from South Dakota.

Welcome, Mr. Chairman.

STATEMENT OF SENATOR PRESSLER

The CHAIRMAN. Well, thank you, Mr. Chairman, for holding this oversight hearing. I shall place most of my statement in the record, but I did want to make a few points.

Within the agency, NASA is committed to cutting $5 billion in 5 years from its budget. This was going to be a formidable feat in and of itself.

The recent House and Senate budget plans to balance the budget by the year 2002 make matters even tougher. Both budget plans assume even deeper budget reductions for NASA.

Many observers believe NASA will have to cut one or more major programs to meet these new budget pressures. Space Station is a conspicuous target. Under NASA's budget plan, the $30 billion Space Station will receive $2 billion a year at a time when other Federal programs are being targeted for cuts or elimination.

In addition, if the Space Station's history is any indication, the $30 billion price tag for the program will probably increase over time. If that happens, the enormous Space Station budget may crowd out other NASA programs more relevant to the taxpayers who pay for them.

I am particularly concerned about NASA's Mission to Planet Earth. I believe Mission to Planet Earth may be NASA's most important program. Using the latest satellite technology, this program will help researchers understand and predict the global climate trends that affect our lives.

As a senator from an agricultural state, I have a keen interest in the program's potential to provide detailed data on soil conditions, topography, crops and other information critical to the farming and ranching community.

I also take great pride in the selection of the EROS Data Center in Sioux Falls, South Dakota, as one of the regional data centers that will collect and distribute the satellite data.

I am very concerned that under these new budget constraints, the Mission to Planet Earth and space science in general may be sacrificed to fund Space Station. That would be a disservice to the Nation and to rural states like my home state of South Dakota.

I have a similar concern with regard to the Shuttle program. NASA's own budget calls for $800 million in unresolved cuts in the

Office of Human Space Flight, which funds both the Space Station and the Shuttle.

If the Station funding is held constant, that reduction would have to be taken completely from the Shuttle. Since 1992, the Shuttle budget has dropped from $4 billion to $3.1 billion, and the work force has been cut by 6,000 people.

Larger cuts already are planned.

Quite frankly, many experts feel there is no more fat left in the Shuttle and that additional cuts cannot be made without compromising Shuttle safety.

Hopefully, Dr. Littles and others can address the problem of how his office will allocate the anticipated cuts in the Office of Human Space Flight.

Finally, Mr. Chairman, I want to express some reservations about the apparent overreliance of our current Space Station plan on the Russians. For example, 44 of the space missions to assemble and supply the station are Russian launches compared with only 27 Shuttle launches.

Moreover, both the navigation system and the crew rescue vehicles are Russian hardware.

To the outside observer, the program increasingly seems to be driven by the Russians and not the U.S. If, for whatever reason, the Russians were forced to withdraw from the Station, the program would collapse, and billions of dollars of taxpayers' money would be wasted.

Accordingly, I am eager to hear of NASA's backup plans to address the possibility of a Russian pullout.

In addition, I would like to hear about safeguards being taken to ensure U.S. technology and dollars being given to the Russians are not diverted to unfriendly hands inside and outside that country.

Again, Mr. Chairman, I thank you for holding this hearing. I look forward to hearing the testimony of our witnesses.

Senator BURNS. Thank you, Mr. Chairman. I appreciate you coming this morning and your interest in this, because I think the Nation is sort of watching this situation and how we operate in our Space Station.

[The prepared statement of Senator Pressler follows:]

PREPARED STATEMENT OF SENATOR PRESSLER

Mr. Chairman, I want to thank you for holding this oversight hearing on NASA's Space Station program. As we all know, the Space Station is under extreme budgetary pressure from within and without the agency. Within the agency, NASA is committed to cutting $5 billion in five years from its budget. That was going to be a formidable feat in and of itself. The recent House and Senate budget plans to balance the budget by the year 2002 make matters even tougher. Both budget plans assume even deeper budget reductions for NASA.

Many observers believe NASA will have to cut one or more major programs to meet these new budget pressures. Space Station is a conspicuous target. Under NASA's budget plans, the $30 billion Space Station would receive $2 billion a year at a time when other federal programs are being targeted for cuts or elimination. In addition, if the Space Station's history is any indication, the $30 billion price tag for the program will probably increase over time. If that happens, the enormous Space Station budget may crowd out other NASA programs far more relevant to the taxpayers who pay for them.

I am particularly concerned about NASA's *Mission To Planet Earth.* I believe Mission to Planet Earth may be NASA's most important program. Using the latest satellite technology, this program will help researchers understand and predict the global climate trends that affect our lives. As a Senator from an agricultural state,

I have a keen interest in the program's potential to provide detailed data on soil conditions, topography, crops, and other information critical to the farming and ranching community. I also take great pride in the selection of the EROS Data Center in Sioux Falls, South Dakota as one of the regional data centers that will collect and distribute the satellite data. I am very concerned that, under these new budget constraints, Mission to Planet Earth, and space science in general, may be sacrificed to fund Space Station. That would be a disservice to the Nation and to rural states like my home state of South Dakota.

I have a similar concern with regard to the Shuttle program. NASA's own budget plan calls for $800 million in "unresolved" cuts in the Office of Human Space Flight (which funds both the Space Station and the Shuttle). If the Station funding is held constant, that reduction would have to be taken completely from the Shuttle. Since 1992, the Shuttle budget has dropped from $4 billion to $3.1 billion and the workforce has been cut by 6000 people. Larger cuts already are planned. Quite frankly, many experts feel there is no more "fat" left in the Shuttle and that additional cuts cannot be made without compromising Shuttle safety. Hopefully, Dr. Littles can address the problem of how his office will allocate the anticipated cuts in the Office of Human Space Flight.

Finally, Mr. Chairman, I want to express some reservations about the apparent overreliance of our current Space Station plan on the Russians. For example, forty-four (44) of the space missions to assemble and supply the Station are Russian launches, compared with only 27 Shuttle launches. Moreover, both the navigation system and the crew rescue vehicles are Russian hardware. To the outside observer, the program increasingly seems to be driven by the Russians, and not the U.S. If, for whatever reason, the Russians were forced to withdraw from the Station, the program would collapse and billions of taxpayers' dollars would be wasted. Accordingly, I am eager to hear of NASA's backup plans to address the possibility of a Russian pullout. In addition, I would like to hear about safeguards being taken to ensure U.S. technology and dollars being given to the Russians are not diverted to unfriendly hands inside and outside of that country.

Again, Mr. Chairman, I thank you for holding this hearing and I look forward to hearing the testimony of our witnesses.

Statement of Senator Hollings

Prepared Statement of Senator Hollings

Today's hearing is an opportunity to get an update on the space station project. It is also an opportunity to ask, once again, whether we should continue this costly project.

Since the early 1980s, this government has faced a steadily growing budget crisis. As a result, we no longer can afford anything but the most essential programs and projects. For that reason, I concluded several years ago that while I am not against the space station in principle, I am convinced we cannot afford it in the present budget environment.

This year, the question of what we can and cannot afford has become even more urgent. The deficit continues to grow, and Congress must finally bite the bullet. I do not agree that the budget resolution now before the Senate actually will balance the budget, for the simple and clear fact that it suggests continued heavy borrowing from the Social Security trust fund. But there is no doubt that agencies such as the National Aeronautics and Space Administration (NASA) face very heavy reductions.

So once again we face the question of priorities—both priorities within NASA and priorities between NASA and other Federal programs. Within NASA, is the space station more valuable to the Nation in terms of new science, environmental information, and economic benefit—than other programs such as space science, aeronautics, and Mission to Planet Earth? And at a time when we see draconian proposals to cut those other Federal science and technology agencies that American industry finds most valuable to U.S. competitiveness, is preserving the space station more important than those other agencies? Or is it more important than education programs?

These are the questions our Committee, the entire Congress, and the Nation as a whole confront. Now is a good time to discuss them.

Senator BURNS. This morning we sort of turned things upside down. I like this way of doing business.

We want to welcome Ms. Lori Garver, who is the Executive Director of the National Space Society—thank you for coming this morning—and Tom Rogers, President of the Space Transportation Association, Dr. Alexander McPherson of the Space Science Work-

ing Group and Association of American Universities, and Marcia Smith, who is Space Policy Analyst for the Congressional Research Service.

We appreciate you coming this morning. And again, I will apologize. We are off to just a little bit of a late start, a couple minutes late. But we will start off with your testimony.

I like the round robin, because I like—if you hear a question that you want to respond to, it just does not have to be directed to you. I like folks who, when we get into sort of a round robin discussion on where we should be going and how we want to get there.

So I will just go right down the line and accept your witness statements and will tell you that your witness statement will be made a part of the record. If you want to shorten that up and give it off the cuff, that is fine with me.

But I welcome Ms. Lori Garver, who is Executive Director of the National Space Society, and thank you for coming this morning.

STATEMENT OF MS. LORI GARVER, EXECUTIVE DIRECTOR, NATIONAL SPACE SOCIETY

Ms. GARVER. Good morning, Mr. Chairman. Thank you very much for having us.

The goal of the National Space Society is to create a space-faring civilization that will establish communities beyond the Earth. And while some may consider the Space Station will be a community beyond the Earth, we view it as a means to an end and not an end in itself.

The International Space Station, if completed, will be able to open the space frontier.

In a recent editorial The New York Times stated that they were critical of the Shuttle and the Station because they were not going anywhere. They made no sense if there was nothing to do beyond them.

Well, we might agree with that if we thought we did not have plans to go anywhere else. But we believe we are going other places, as you spoke this morning.

The Space Station should be viewed not as just another step in a long-term purely government space activity, but as the opening wedge for large-scale, non-government activity in space. If budgets must be cut to the point that all remains is the Shuttle and the Station, we would be forced to reconsider our support.

The recent NASA zero-based review, however, is a strong and positive contribution to reducing institutional overhead and duplication while keeping the important elements and programs key to our future in space.

In particular, we speak of the Discovery Mission, Lunar Prospector, of the Reusable Launch Vehicle technology programs, X–33 and X–34, and of the Space Station. We believe these programs provide the critical seed corn for our future.

We suggest that in a unique post–cold war NASA, a role can be found in developing the technologies and gaining the necessary data for human expansion into the solar system. The ultimate purpose of NASA should be to empower individuals and private organizations to go into space for their own reasons.

The primary justification for the Space Station is that it will provide a place for learning about living and working in space.

This includes not only life sciences research to prove that humans can survive for long missions that would be necessary, for instance, on a human expedition to Mars, but tools, pressure suit designs, psychology of long-term space operations, measuring human productivity in space, and life support technology.

The important thing is that the Space Station capabilities and plans for its utilization should be evaluated in this long-term plan, developing the necessary skills to commit much larger human presence in space.

The international cooperation, we believe, adds significant value to the project. While the roles of the traditional U.S. partners have been modified and altered by the entrance of Russia into the cooperative project, Canada,

Japan and the European Space Agency are still providing billions of dollars in components to increase the station's effectiveness.

Furthermore, the Russian contribution to the Station design, auxiliary vehicles and launch capabilities should enhance station robustness and reliability and decrease the direct cost to the United States of developing and operating the program.

In general, the marriage of the American and Russian space programs, we believe, is a promising one. Our biggest problem is high cost. Russia's greatest strength is low cost.

Our worst disadvantage is inexperience with permanent occupied orbital facilities. And Russia has been building and operating such facilities since the late seventies.

Our partnership allows for results that neither could obtain alone at a significant savings to both countries. Future solar system exploration will most likely be in a partnership with other space faring nations. The experience of working together on the Station will be important.

Of course, there is the warning. A U.S. failure to successfully carry out its obligations on the International Space Station over the coming decades will likely damage future prospects for high technology cooperation and possibly with broader foreign policy interests.

As a grass roots group, we do not speak with authority about the many difficult technical decisions involved in bringing the Station into a reality, but we can say that the use of the Station is of paramount importance. The Station cannot become an end in itself or it will not survive.

Policies for allocation of resources aboard the Station must allow for significant use by commercial R&D projects coupled with a realistic pricing policy to ensure its most productive use.

Plans for the Space Station should allow for potential commercial opportunities for Station operation and servicing.

It should be the center of a growing civilian and commercial presence, not simply an end point of one government program.

The partners should consider selling the Space Station to the private sector at the end of its design life. And finally, the U.S. Government's space projects belong to all Americans.

In overseeing the money that goes into the NASA budget, you can ensure that what comes out of it represents all Americans by

supporting a station that will develop capabilities to eventually allow the public the opportunity to personally travel in space.

The editors of The Times were right, in our opinion, that a space program that constitutes business as usual will surely fail. Where they were wrong was in their inability to imagine a space program that does not constitute business as usual. We know that many of you already understand this point and urge you to put our shared view into practice.

We have detailed recommendations in our statement submitted for the record. In summary, they are the following:

- Either fund the Space Station or kill it. We believe that the existing program deserves support.
- Demand measurable performance from NASA and industry.
- Begin to fly hardware immediately.

Our 25,000 members have consistently supported the Station in policy polls year after year. If it were canceled, we would not go away. We have supported a Station since 1979, and we are now on our way to getting that important foothold.

Thank you very much.

Senator BURNS. Thank you, Ms. Garver. We appreciate your comments this morning.

[The prepared statement of Ms. Garver follows:]

PREPARED STATEMENT OF LORI GARVER

I would like to thank you, Chairman Burns, and the other members of the subcommittee, for giving me the opportunity to testify today. You are hearing a great deal from experts at NASA and in the aerospace industry regarding the fixture of the NASA budget and of our nation's space policy. I would like to add some suggestions from the National Space Society, a grassroots organization representing tens of thousands of ordinary Americans who want to see a flourishing space program that produces real results, not simply jobs and contracts.

THE VISION OF THE NATIONAL SPACE SOCIETY

The National Space Society is dedicated to the creation of a space-faring civilization and the establishment of communities beyond the Earth. Our mission is to promote change in social, technical, economic, and political conditions when people will live and work in space. We believe that the technologies and industries created on the space frontier will be of benefit to all humanity in the coming century. We further believe that opening the space frontier will create new opportunities for human life, liberty, and the pursuit of happiness.

Space activities today are still largely driven by governments. In the United States, the NASA budget was about $14.5 billion, reported military space activities were about $15.1 billion, and commercial space revenues were about $6.5 billion.[1] Yet total commercial space revenues have been growing at an average of 20 per cent per year for the last five years, some years being better than others. In contrast, U.S. government space spending will stay flat at best in constant dollars and will more likely decline. This is certainly true of NASA and may be true for the Department of Defense as well. What this means is that commercial space revenues from communications, remote sensing, and satellite navigation (e.g., the Global Positioning System) will increase in importance. At current growth rates, commercial space will account for 40 per cent of U.S. space spending in the year 2000—five years away. If the growth rate drops in half, to 10 per cent per year, commercial space will still account for 28 per cent of U.S. space spending (Figure 1).

---

[1] Library of Congress, *Military Space Programs: Issues for the 104th Congress,* Marcia S. Smith, Congressional Research Service, 95-95 SPR, January 11, 1995; U.S. Department of Commerce/International Trade Administration, *U.S. Industrial Outlook, Chapter 28—Space Commerce,* U.S. Government Printing Office, Washington, DC., January 1994.

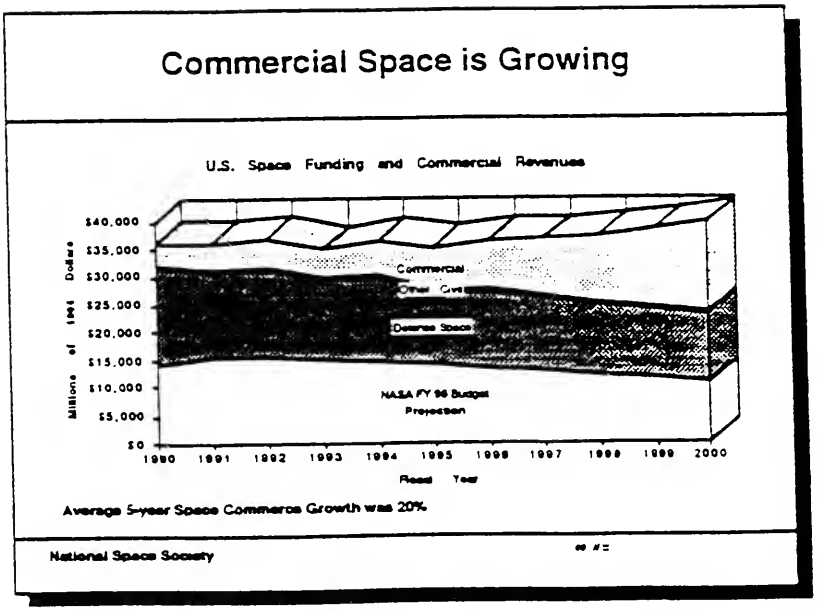


Figure 1

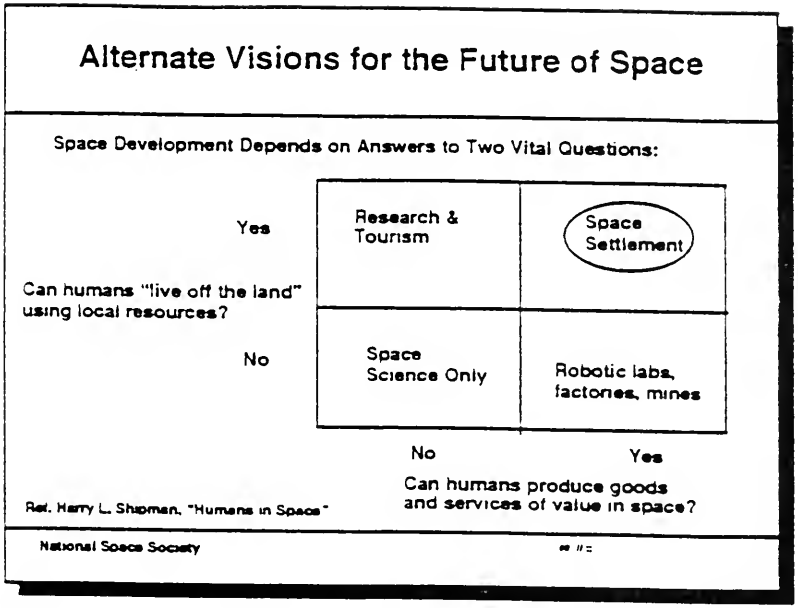
The National Space Society does not believe that the settlement of the Solar System can be accomplished with any single government program or even the cooperative efforts of many governments. Rather, space development and settlement will occur most effectively when the economic, technical, and social conditions allow individuals and non-governmental organizations (such as private firms and non-profits) to move into space on their own. The barriers to space development are many, but they can be put into two general categories: 1) immature, expensive technologies; and 2) government policies. The National Space Society supports efforts to remove both kinds of barriers.

There are many possible outcomes for the future of space development. In his book, "Humans in Space—21st Century Frontiers," Harry Shipman poses two cardinal questions.[2] First, can extraterrestrial resources be used to support humans in space? Second, will space industrialization work? That is, can we "live off the land" and can we produce something of value to pay our way. If the answers to both questions are yes, than space settlement can occur. If the answers to both questions are no, then space is a realm for science and a few important, but earth-focused missions such as weather monitoring. If we can live off the land, but not produce anything of value, then space will be like Antarctica—a place for research and tourism, but not much else (Figure 2).

The members of the National Space Society believe the answers to both questions are yes. But belief is not the same as knowing. The answers to these questions produce such dramatically different outcomes for the future of space development that a modest level of public effort should be dedicated to answering them. I should point out that the Congress has already laid the basis for such efforts with passage of the 1988 Space Settlements Act.[3] This Act declares that "the extension of human life beyond Earth's atmosphere, leading ultimately to the establishment of space settlements" is a national goal requiring periodic reporting by NASA regarding how its programs are to advance this goal. With the exception of one report during the ill-

[2] Harry L. Shipman, Humans in Space—21st Century Frontiers, Plenum Press, New York, 1989.

[3] Public Law 100-685, sec. 217; 102 Stat 4094; codified at 42 U.S.C. 2451 (1988).



(Figure 2)

fated Space Exploration Initiative effort, NASA has failed to provide the required reports to the Congress.

The lack of NASA reporting on progress toward space settlements is in part understandable. As long as such efforts were seen as requiring hundreds of billions of government-supplied dollars over decades, it was clear that the necessary political support would hardly be forthcoming after the end of the Cold War. NASA needs to recognize that it will not settle the space frontier any more than the Department of War and the Department of Agriculture settled the American West. **We suggest that a unique, post-Cold War role for NASA can be found in developing the technologies and gaining the data necessary for human expansion into the solar system. The ultimate purpose of NASA should be to empower individuals and private organizations to go into space for their own reasons.** Even in the present tough fiscal environment NASA can make valuable contributions to answering the questions I've poised. NASA is working with industry to lower the cost of access to space through the X-33 program, it is seeking to acquire information on local space resources through low-cost efforts such as the Lunar Prospector, and it can help create the tools necessary for space-based industries through the Space Station. As NASA Administrator Goldin has recognized, it is precisely the pressure of these budgets that create the incentives to think anew about a sustainable, long-term future for NASA.

In a time of down-sizing and reduced resources, NASA needs to decide what its core competencies should be and how to maintain them. The recent NASA Zero Base Review is a strong and positive contribution to reducing institutional overhead and duplication. Since the debate over NASA's future is well under way, allow me to be blunt. Many proposed NASA missions could, in the extreme, be done by other agencies. Science, environmental monitoring, even space operations themselves, could be done by the National Science Foundation, the National Oceanic and Atmospheric Administration, and the Department of Defense; although the character of these operations would change to match their new homes. Space science and technology are the core of NASA but it is unclear what purposes this capability should serve. In a March 6 editorial, the New York Times said that the "space station makes mini-

mal sense unless it is part of a broader plan of space exploration."[4] This is a vulnerability at the heart of NASA. A way must be found to give NASA a new post-Cold War purpose in light of fiscal realities or this unique agency will sooner or later close shop.

The New York Times criticized the Space Station and the Space Shuttle as making no sense because we have nowhere to go after them. In this, as is often the case, the editors of the Times were just about half right. The Space Shuttle and the Space Station would make little sense if we had no plans to go beyond them. But we do. The important thing is to ensure that our entire space program reflects those plans. And even in these times of strangled budgets, there are still things that we can do to promote progress toward the long term goal of opening the space frontier. The key fault in the Times' approach is its assumption that nothing significant will ever be done in space unless the government does it. But in fact, the Space Station should be viewed not as just another step in a long-term plan of purely government space activity, but as the opening wedge for large scale nongovernment activity in space. It will serve this purpose well if we pursue the proper policies over the next few years.

The National Space Society is not by definition a NASA supporter. Rather, we are supportive of NASA as their efforts coincide with our goals. We stress that the opening of outer space as the next frontier, should serve as the overarching consideration against which all space policy and budgetary decisions are weighed. From our perspective, promoting space settlement is the only overarching goal for the Space Station; all other purposes, such as earth observation, astronomy, and the generation of general scientific knowledge, are secondary. Our views are based on this perspective. I will discuss a number of issues in this light.

THE ROLE OF THE SPACE STATION

Learning to Work in Space

The primary justification for the Space Station is that it will provide a place for learning more about living and working in space. This includes not only the "life sciences" research needed to determine whether humans can survive extended periods of microgravity in the context of, say, human missions to Mars. It also means much more basic things like tool and pressure suit design, psychology of long-term space operations, human productivity in space, life support technology, and so on. The important thing is that Space Station capabilities, and plans for Space Station utilization, should be evaluated in the context of a long-term plan for developing the necessary skills to permit much larger-scale human presence in space

The Space Station has to accommodate many diverse interests. On one hand, it is supposed to create operational capabilities such that the human presence in space may become "routine." Others insist it should be a major facility for commercial and industrial research. Still others say its primary purpose should be to advance state of the art science and technology. The Station will present its own set of unique problems that will make meeting these different objectives a challenge. Scientific and commercial users will want high amounts of communications bandwidth to monitor and control there experiments. The local area around the Station is likely to be "dirty" making vacuum-related research difficult. The constant shifting of crews, resources, and experiments will make it hard to maintain a "quiet" Station for microgravity researchers. There will be problems with equipment racks, stressed by launch into orbit, not fitting properly into their designated slots. Experiments will prove balky and take longer to hook-up than expected. Provisions will need to be made to deal with hazardous materials in and around the Station. And while critical areas of the Station itself may have protection against orbital debris, there will still be uncertain risks to crews working outside in pressure suits.

Space manufacturing, building large structures, and managing complex operations in remote and hostile environments are all skills that we will need to step further beyond Earth. There is a lot about living and working in space that we don't know, such as the most effective mix of humans and machines. As the Space Station develops the engineering skills for routine operations in space and on the ground, attention must be paid to areas such as a automation, robotics, and artificial intelligence systems. Only with technologies such as these will the human exploration of our ultimate frontier move forward.

International Cooperation

The Space Station is an international effort linking many nations. While the roles of the U.S.'s traditional partners have been altered with the entrance of Russia into the cooperative project, Canada, Japan, and the European Space Agency are still

[4] *New York Times*, Editorial March 6, 1995, pg. A14.

providing billions of dollars in components to increase the Station's effectiveness. Furthermore, Russian contributions to Station design, auxiliary vehicles, and launch capabilities should enhance Station reliability and decrease the direct cost to the United States of development and operating expenses. While the U.S. will retain its role as the primary operator of the Station, Russian control facilities, launching inclinations, and experience will make the overall management of the Station more versatile and comprehensive.

The marriage of American and Russian space programs is a promising one. Our biggest problem is high cost; Russia's greatest strength is low cost. Our worst disadvantage is inexperience with permanently manned orbital facilities; Russia has been building and operating such facilities since the late seventies. We need experience with how people behave and adapt in the space environment. With Russia, we have begun the acquisition of this knowledge through collaboration aboard their presently orbiting facility, Mir. Partnerships that include the American and Russian programs can obtain results that neither could obtain alone, and at significant savings to both countries. A U.S. failure to successfully carry out its obligations to the international Space Station over the coming decades will likely damage future prospects for high technology cooperation as well as broader foreign policy interests.

If the United States and humanity are to ever expand into the solar system, it will most likely be in partnership with other spacefaring nations. The experience of working together on the Space Station will create problems in everything from incompatible technical standards and logistic support to cultural misunderstandings and legal disputes. The inclusion of Russia in the international Space Station has certainly provided examples of these challenges. But in the process of overcoming these problems together, we will be creating the strong foundations for a truly spacefaring civilization.

Meeting the Needs of Space Station Users, Customers, and the American People

As a grassroots group, we cannot speak with authority about the many difficult technical decisions involving in bringing the Station into reality. What we can say is that the use of the Station is of paramount importance. The inevitable tensions between space system operators and users goes back to the earliest days of spaceflight. Even though space system operators would often like to left alone and not have to deal with pesky users, it is the users that provide the rational for spaceflight projects. The Station cannot become an end in itself or it will not survive. Station resources such as volume, power, and the other utilities, crew time, and payload capacity up and down must be available in significant quantity beyond those resources needed to build and operate the Station itself. Policies for allocation of resources must allow for significant use by commercial R&D projects coupled with a realistic pricing policy to ensure the most productive use of the Station.

The Space Station design should be allowed to grow and change to accommodate different needs and wants as we move down the learning curve. Perhaps in the future users will move off the first Space Station to smaller robotic, or crew-tended stations of their own. A spacefaring civilization is unlikely to need only one Space Station, but will want several stations that separate research programs with conflicting requirements. This means that plans for the Space Station should allow for potential commercial opportunities for station operation and servicing. The Space Station should serve as the center of a growing civilian and commercial presence, not simply as the endpoint of a government program.

The Space Station partners, and especially the United States, should encourage efforts to supply privately developed systems for the diverse needs of the Space Station itself and those who will use this new international facility. This approach not only provides opportunities for the private sector, but creates options for Station users and reduces governmental risk in developing new space capabilities. In keeping with this approach, the partners should consider selling the Space Station to the private sector at the end of its design life.

The Station should be user friendly, and should accommodate people other than scientist/astronaut types. Space belongs to everyone, not just a few civil-service thoroughbreds, and recognizing this will help promote public involvement in the space program—and help build a knowledge base for space settlement, since space must ultimately be settled by ordinary people, not just the highly trained specialists who constitute most space travelers today.

This last point is in many ways the most important. U.S. government space projects belong to all Americans. One reason why such efforts have suffered in public esteem lately is that it has seemed an exclusive preserve of astronauts, bureaucrats, and contractors, leaving the American people feeling disconnected and distant. The money being spent on space programs belongs to the American people, not to the government and corporate officials who spend it.

In overseeing the money that goes into the NASA budget, you should ensure that what comes out of it represents all Americans, by supporting a Station that will develop capabilities that will eventually allow all Americans the opportunity to personally travel into space and develop new communities for themselves and their children if they so choose. A program that has that aim, and that pursues it credibly, will find political support easy. The editors of the Times were right that a space program that constitutes business as usual will surely fail. Where they were wrong was in their inability to imagine a space program that does not constitute business as usual. We know that this Congress already understands this point, and urge you to put our shared vision into practice.

RECOMMENDATIONS

The problems of the Space Station program to date have not been primarily technical, but managerial, and have stemmed from a sometimes unclear sense of what the Station should be for. The explicit adoption of our vision in the Station design process would have solved many of these problems, and provided a clear touchstone for evaluating different technical proposals. It still can and we have a few observations and recommendations to make:

- Either fund the Space Station fully or kill it. Do not cut it again or subject it to another redesign. There will be difficult decisions for NASA by pressing ahead with Station, but we agree with the NASA Administrator that it is time to get on with the program and make it work. We are sometime asked what we would do if the Station were canceled. If that were to happen I can promise that we would not go away, but will come back to press for a permanent human return to the Moon with as many international partners as will still talk to us. We strongly urge the adoption of a multi-year authorization for the Space Station as a means of providing needed stability to the Station program and the plans of our spacefaring partners.
- Demand measurable performance and results from NASA and industry. Do not convene another commission, but ensure that there is a government mechanism for continuing, consistent, competent, non-advocacy reviews of Space Station progress. In particular, require outside (i.e., non-NASA) reviews of the resources, policies, and plans to support Space Station utilization.
- Press forward with flying hardware to separate the real engineers from the vugraph artists. Be willing to support evolutionary improvements as we gain operational experience living and working in space.
- Develop long-term plans for the human expansion into space to provide a context for the role of the Space Station. New technology developments should support decisions for a permanent return to the Moon and human self-sufficiency in space.

We should work to ensure that the new millennium does not ring in with a space program like that of two decades ago—a space station burning up upon re-entry and no human access to space. An environment must not be created in which new and innovative programs are stretched out due to unstable budgets. We hope to work with this Congress to ensure that the new millennium begins with a permanently occupied international Space Station, testing of a new fleet of reusable space launch vehicles, and innovative, frequent missions to the Moon, Mars, and the asteroids.

Senator BURNS. We call on Mr. Tom Rogers, who is President of the Space Transportation Association. What a great name to be involved in in the interest of space.

Mr. ROGERS. Rogers, Mr. Chairman? Buck.

Senator BURNS. Yes. May I call you Buck?

Mr. ROGERS. Ginger. [Laughter.]

Senator BURNS. All right.

STATEMENT OF TOM ROGERS, PRESIDENT, SPACE TRANSPORTATION ASSOCIATION

Mr. ROGERS. Mr. Chairman, Senator Pressler, a dozen years ago, I directed the Space Station study conducted by the Congress's Office of Technology Assessment.

Today, I would urge you to begin to look at the Space Station in a new and an additional light, one that reflects both space-related lessons that we learned in the past few years and today's space and

economic circumstances, for the Space Station should play an economic role well beyond that now expected of it.

While you should continue to be interested in Alpha's internal capabilities, you should now also begin to think of it as Representative Robert Walker does, in effect, as the public centerpiece of a private sector space business park. Private sector modules would surround Alpha, providing residential and working space with all required utilities.

Such an arrangement would allow Alpha's capabilities to be expanded at no additional public cost and a variety of commercial activities to commence in low earth orbit.

Taking advantage of lessons learned in the Space Station program and elsewhere and using free enterprise methods, including private financing, such infrastructure can be acquired and operated at low unit cost.

Cargo and people would be carried to and from the park with commercial follow-ons to the administration's X–33 and X- 34 programs safely, reliably and also at low unit cost. A unit cost reduction of an order of magnitude is expected and, with sufficiently large markets, of two orders of magnitude.

To accomplish this, new and innovative public-private institutional arrangements will be required for a transitional interval, arrangements that would compliment the novel technologies now under development in the space living quarter and transportation areas.

The Congress will play a central role in the fashioning of such arrangements. For instance, the Secretary of Defense has just suggested some ways to you by which our private sector could invest in and speed up the improvement of military family housing. He suggested to you that "with the help of the Congress and the private sector, we can drive down its cost while accelerating the process from 30 to about 10 years."

When such private sector infrastructure and public- private institutional arrangements become available to space, recent studies, one by an aerospace committee of the Institute of Electronics Engineers, a study which I headed, and another conducted by an alliance of six major aerospace firms, show that new private sector activities can be expected to commence in low earth orbit.

One such example is expected to be that of space tourism.

Polls have indicated that some 80 million United States adults would like to take a trip to space—80 million! And a recent professional market survey in Japan prompted the conclusion there that a space tourism business could expect to gross $10 billion a year.

In March, the Speaker of the House of Representatives,

Newt Gingrich, noted that "Tourism and travel is the second largest industry on the planet.... A major profit center in space will be operating a hotel there."

I can readily imagine such a hotel being located near the Space Station where tourists could view it and the activities going on there and be visited by its crew members during their R&R intervals.

A cooperative study is now being contemplated by the Space Transportation Association to see what is required to initiate a space tourism business here. And a private sector venture is al-

ready underway that is aimed at providing a space business park centered on Alpha.

In brief, Mr. Chairman, I now envision the Space Station becoming a physical and institutional center for the expansion of low earth orbit economic activity. That is, the historical role of our Federal Government will begin to be fulfilled in space.

The government, using public funds, opens up new territories in space, creates the first one, thereby allowing private interests to enter them, reside there and develop and use them for private purposes.

Mr. Chairman, our entire perspective about space, I am sure, will change in the next several years.

Thank you for inviting me here today.

Senator BURNS. Mr. Rogers, that intrigues me that we may have another land rush. Is that what you are trying to say?

Mr. ROGERS. I hope so.

Senator BURNS. The "Sooners" are coming again.

Mr. ROGERS. I hope so.

Senator BURNS. Good.

[The prepared statement of Mr. Rogers follows:]

PREPARED STATEMENT OF MR. ROGERS

A dozen years ago Dr. John Gibbons, now the President's Advisor on Science and Technology, then the Head of the Congress's Office of Technology Assessment, persuaded me to direct OTA's Space Station study.

Since then I imagine that the Space Station program has received nearly as much attention by the Congress as the financing of our Nation's health care. I do not judge that I can add anything useful to considerations of its present cost, capability, schedule, international character, etc.

Rather, what I will do today is to urge you to look at the Space Station in a new, additional, light—one that reflects both space-related lessons that we have learned in the past few years and today's space and economic circumstances. For, in my judgment, the Space Station is now poised to play an economic role well beyond that generally envisioned for it. And, on the civil side, the central thrust of our Nation's space activities should become, and can become, economic rather than cultural or political.

In January, Representative Robert S. Walker, the new Chairman of the House Committee on Science, spoke to the Space Transportation Association. In effect he said that he now thinks of the Space Station as a public centerpiece of what should become a private sector "Space Business Park." Such a "Park" would provide appropriate residential and work space and utilities assembled in close orbital proximity to the Space Station. This would allow a large number of diverse business activities to be conducted in Low Earth Orbit. Some of these initial activities would increase the capabilities of the Space Station at no additional public cost. Others would be commercial activities from the outset.

I agree with Rep. Walker's view.

I had an exchange of correspondence with him in February in which I asked him for his views re the desirability of commencing business activities in concert with the Space Station. He replied "...applying the lessons of market economics to the Space Station program can, and should, begin now—not after [it] is built."

The Space Station should become a physical and institutional center for the expansion of LEO economic activity. The historical role of our Federal government in opening up new territory that soon thereafter is entered by private sector interests would thus begin to be accomplished.

Because it would be financed, designed and constructed by private sector interests as a profit-seeking investment; because of technological and operational lessons being learned in the Space Station program and in other space areas; and because our government, commercial and industrial space offices now fully appreciate the necessity of reducing the unit cost of basic space infrastructure, we can look forward to seeing this additional business-related capability come on stream at unit costs that will allow their widespread private use.

To see the early realization of such a Space Station-related "Space Business Park" and its large-scale free enterprise use we will have to create new, cooperative and imaginative private sector-government institutional arrangements. The Congress may well play a central role in the fashioning of such arrangements.

For instance, in this regard you could note the innovative legislation proposed by the Secretary of Defense two weeks ago related to the use of private capital to quickly improve Defense's military family housing.

In order to reduce costs and speed construction he advances such concepts as guaranteed rental payments, long-term lease commitments, and backup mortgage insurance. Just as we in the space area, the Secretary judges it to be necessary, and possible, "...with the help of the Congress and the private sector...to drive down the cost of [this infrastructure] while accelerating the [process] from 30 to about 10 years." That is, in the space infrastructure area we must now begin to be as creative about our institutional arrangements, especially cost-price arrangements over a transitional interval, as we have been about space science, exploration and technology development.

As you heard in testimony here a week ago, the last year has seen important strides taken in the space transportation area: policy strides by the White House and program strides by NASA in cooperation with our space industry. The X-33 and -34 programs offer the distinct promise of surface-LEO people and cargo transportation becoming much more safe and reliable and much less costly—almost certainly by an order of magnitude and, with large enough public and private markets, by two orders of magnitude.

I see the Space Station program and related private LEO infrastructure activities taking their place alongside the X vehicle infrastructure programs as building blocks to be used to (finally) open up Low Earth Orbit to the general public and to large-scale free enterprise.

The Congress has reason to expect that, with the successful provision of such new, much lower unit cost, space infrastructure elements, the long heralded and long deferred full economic promise of space can finally begin to be realized. For we will soon be able to travel to and from orbit at times of our own choosing and remain there for long intervals, and if desired in privacy, with great safety and for prices that will be acceptable to private, and in some cases even individual, interests.

For, under such markedly improved circumstances, we now have every reason to judge that a large number of private space activities will be undertaken—activities that, since the beginning of the space age, have been closed to private initiative. Two recent studies in the United States have identified several business areas—some novel to the usual science- and exploration-oriented ways of thinking about space—that look quite attractive. One was conducted by the Aerospace Research and Development Policy Committee of the United States element of the Institute of Electrical and Electronics Engineers ("What The United States Must Do To Realize The Economic Promise Of Space ") and the other by an "Alliance" of six aerospace companies (the "Commercial Space Transportation Study ").

These studies are quite clear, indeed emphatic, in their general conclusions: get safety and reliability of basic space infrastructure up, sharply, and get its unit cost down, sharply, and we will see space-related business burgeon far beyond the some $7 billion/year level already reached in the satellite communications area today.

Let me single out just one of these new business prospects: that of space tourism.

Polls conducted in the United States in the 1980s found that 40%-45% of our adult population wanted to take a trip to space—some 80 million of us! That conclusion was also reached in the United Kingdom.

Just last year, a professional market study was conducted in Japan that convinced important space professional and business interests there that a space tourism business could be created that would gross some $10 billion per year! Their studies advanced to the point where they designed a conceptual space tourism service vehicle, made a physical model thereof, and displayed it at last year's Farnborough, England, airshow. (See the current issue of *The Journal of Practical Applications in Space.*)

Two years ago *Barron's* business and financial weekly editorialized "We know that many...of Earth's citizens, including the present writer, would drain their bank accounts, max out their credit cards and sell their most cherished possessions to finance a...trip to space." And the Speaker of the House, Newt Gingrich, observed in March this year: "Tourism and travel is the second largest industry on the planet. ...a major profit center in space will be operating a hotel [there]." I can easily picture such a hotel being located near the Space Station where visitors could view it and the activities going on there and be visited by its crew members during their R&R intervals. Just imagine how much differently we would begin to think about

and value space when large numbers of us can regularly visit there and we can see for ourselves large-scale space businesses being carried on.

The Space Transportation Association is now considering the conduct of a wide cooperative study of what considerations would enter into the creation of a U.S. space tourism business, and the private sector-government steps that should be taken to hasten the day when such a business prospect comes into being. Such a study could examine the use of our Shuttle fleet and the Space Station in the conduct of market research and demonstration in addition to our present plans to use them for scientific research and technology development-demonstration.

And the Sophron Foundation is encouraging U.S. interests who are considering the early conduct of a professional space tourism market survey in the United States.

Finally, while business proprietary considerations do not now allow me to provide you with details at this time, you should know that there is a group of private business interests that are now going about the creation of a Space Station-related "Space Business Park" and the delivery of LEO services.

In brief: we should all begin to appreciate that our publicly funded Space Station and space transportation efforts can now begin to position the United States to attain the economic "pay off" stage in space. With a Federal government commitment to work closely and cooperatively with our private sector, and with creative public-private arrangements in place over some transitional interval, the economic value of space to the Country will begin to be sharply increased and broadly appreciated. Thank you for inviting me here this morning.

[The biography information provided with prepared statement is maintained in subcommittee's file]

Senator BURNS. Dr. Alexander McPherson, who is representing the Science Space Working Group and the Association of American Universities from California, I think you are out there and thank you for coming.

We appreciate that very much.

STATEMENT OF ALEXANDER MCPHERSON, SPACE SCIENCE WORKING GROUP, ASSOCIATION OF AMERICAN UNIVERSITIES

Dr. MCPHERSON. Thank you, Mr. Chairman, for inviting me to come here today and sharing with you a few thoughts as a representative of the space scientists who intend to use the Space Station in their own future research.

I would like to begin by affirming once more the steadfast and unequivocal endorsement of the microgravity and life science community for continued support of Space Station as it is currently configured.

I would like to further assure you that the consensus view of this vast community of scientists is that Space Station will serve as a research platform, providing unique and unparalleled opportunity for a broad array of scientific disciplines.

This is now evidenced by highly favorable reviews in the scientific press, and I call your attention to the recent issue of "Science Magazine," which carries a very favorable article on the life sciences and microgravity sciences.

It also features on its cover a protein structure, which is derived from crystals very much like those that we have growing in space and then in fact are featured later on in that article.

It is evidence as well by this report of the National Academy of Science's Space Study Board entitled, "Microgravity Research Opportunities for the 1990's," which details those opportunities and those programs which are likely to hear fruit to the scientific community in the next century, and the increased public support and expectations that daily appear in the popular press that reinforce that as well.

Space Station is and will remain into the 21st century the flagship scientific enterprise of the National Aeronautics and Space Administration. It will be the premier scientific initiative of the citizens of the United States.

Its continued support is justified and necessary to maintain the American spirit for scientific quest and exploration, to provide inspiration to its youth, and to promote the scientific, educational and commercial interests of the country.

As detailed in the report of the National Academy of Sciences Space Studies Board, there are microgravity programs in the fields of fluid dynamics, biotechnology, protein crystal growth, metallurgy and materials processing, combustion, heat and mass transfer, and questions of pure physics.

The currently planned laboratory for Space Station and the environment it will provide has now been rigorously assessed by the scientific community over many years, and it has their strong endorsement.

The inclusion now of attached payloads increases substantially its scientific capabilities and value. The integration of commercial programs and facilities further enhances its worth, both extending the basic scientific component and returning useful space science to its proper owners, the people of the United States.

If I can address just a couple of comments to the budget issues. The Space Station program, after much turmoil and restructuring, appears, in our view, well on track at this time. The new consolidated management structure is proving itself highly efficient, thrifty and effective.

The science programs that will utilize Space Station are being brought into readiness, experimental designs completed and instruments fabricated.

The current schedule and pathway for Space Station assembly is realistic and supported by the community of scientific users. We believe that this year's budget and those for outyears are spartan, but realistic, and adequate to assure human safety and the scientific integrity of Space Station.

In the area of international cooperation and utilization of Space Station, I would assure you that NASA is now moving swiftly to increase the level of cooperation between partners and ensuring that a coordinated effort is made to optimize the scientific resources provided by Space Station.

It is currently developing an internationally integrated scientific manifest for Space Station and recently constituted a task force to evaluate international issues.

This group has strongly endorsed the current direction of increased international cooperation and advances the concept of Space Station as a laboratory without walls.

My own laboratory is actively working in collaboration with Russian scientists and Russian Space Agency officials to prepare the first American–Russian protein crystallization experiments to be carried on the Russian Space Station Mir.

This experiment will be carried aloft by the U.S. Space Shuttle in late June of this year. That collaboration has proceeded with a spirit of close cooperation and good will, and we have reason to believe that this mutual attitude will continue into the future.

Regarding the Russian participation in our Space Station effort, I cannot speak with complete knowledge or authority, only as a collaborating scientist.

My impression, however, is that safety issues and other operations questions that might impact overall success are considered with as much gravity and concern by the Russian contingent as our own. I am not at this time concerned that failure on the Russian side is likely to seriously jeopardize our own chances of success.

In closing, let me once again emphasize that Space Station may well become America's scientific symbol of excellence, its badge of courage, its most visible expression of leadership into the 21st century. As scientists and explorers, we encourage you to stay the course.

Thank you.

Senator BURNS. Thank you, Dr. McPherson.

[The prepared statement of Dr. McPherson follows:]

PREPARED STATEMENT OF PROFESSOR MCPHERSON

Mr. Chairman, I would like to begin by affirming once more the steadfast and unequivocal endorsement of the microgravity and life sciences community for continued support of Space Station as it is currently configured. I further assure you that the consensus view of this vast community of scientists is that Space Station will serve as a research platform providing unique and unparalleled opportunity for a broad array of scientific disciplines. This is now evidenced by highly favorable reviews in the scientific press (*Science*, April, 1995), the recent report by the National Academy of Sciences Space Studies Board (*Microgravity Research Opportunities for the 1990s* - April, 1995), and the increased public support and expectations that daily appear in the popular press.

Space Station is, and will remain into the twenty first century, the flagship scientific enterprise of the National Aeronautics and Space Administration, and the premier scientific initiative of the citizens of the United States. Its continued support is justified and necessary to maintain the American spirit for scientific quest and exploration, to provide inspiration to its youth, and to promote the scientific, educational and commercial interests of this country.

As detailed in the report of the National Academy of Sciences Space Studies Board, there are strong microgravity programs in the fields of fluid dynamics, biotechnology and protein crystal growth, metallurgy and materials processing, combustion, heat and mass transfer, and questions of pure physics. The currently planned laboratory for Space Station, and the environment it will provide, has been rigorously assessed by the science community, and it has their endorsement. The inclusion now of attached payloads increases substantially its scientific capabilities and value. The integration of commercial programs and facilities further enhances its worth, both extending the basic scientific component and returning useful space science to its proper owners, the People of the United States.

The Space Station program, after much turmoil and restructuring, appears well on track at this time. The new, consolidated management structure is proving itself highly efficient, thrifty, and effective. The science programs that will utilize Space Station are being brought into readiness, experimental designs completed, and instruments fabricated.

The current schedule and pathway for Space Station assembly is realistic and supported by the community of scientific users. We believe that this year's budget, and those for out years, are Spartan, but realistic, and adequate to assure human safety and the scientific integrity of Space Station.

In the area of international cooperation and utilization of Space Station, I would assure you that NASA is now moving swiftly to increase the level of cooperation between partners and insuring that a coordinated effort is made to optimize the scientific resources provided by Space Station. It is currently developing an internationally integrated scientific manifest for Space Station, and recently constituted a task force to evaluate international issues. This group has strongly endorsed the current direction of increased international cooperation and advances the concept of Space Station as "A laboratory without walls".

To provide but one example of the international cooperation that currently exists; I am not only principal scientific investigator of several NASA supported flight ex-

periments, but I serve on the advisory council of the European Space Agency for this activity, work with their prime contractor Dornier Aerospace Co., and have joint experiments planned with ESA investigators. I was a plenary speaker at the Japanese INSPACE conference in Tokyo in November, and a similar conference held by the Canadian Space Agency in Toronto in January. This example is not unique, but characterizes the activities of many of the scientific investigations planned for Space Station.

My own laboratory is actively working in collaboration with Russian scientists and Russian Space Agency officials to prepare the first American-Russian protein crystallization experiments to be carried out on the Russian Space Station Mir. This experiment will be carried aloft by the U.S. Space Shuttle in late June of this year. That collaboration has proceeded with a spirit of close cooperation and good will, and we have reason to believe that this mutual attitude will continue into the future.

Regarding the Russian participation in our Space Station effort, I cannot speak with complete knowledge or authority, only as a collaborating scientist, but my impression is that safety issues and other operations questions that might impact overall success are considered with as much gravity and concern by the Russian contingent as by our own. I am not, at this time, concerned that failure on the Russian side is likely to seriously jeopardize our own chances of success.

In closing, let me once again emphasize that Space Station may well become America's scientific symbol of excellence, its badge of courage, its most visible expression of leadership into the twenty-first century. As scientists and explorers, we encourage you to stay the course.

[The biography credentials provided with prepared statement is maintained in subcommittee's file]

Senator BURNS. And now we welcome Ms. Marcia Smith, who is Space Policy Analyst for the Congressional Research Service. And thank you for coming this morning.

STATEMENT OF MARCIA S. SMITH, SPACE POLICY ANALYST, CONGRESSIONAL RESEARCH SERVICE

Ms. SMITH. Mr. Chairman and Mr. Chairman, thank you for inviting me here today to testify about the progress that has been made on the Space Station program and the challenges that remain.

As you requested, I will focus mostly on the challenges. My written testimony provides more details on these matters.

There has been progress in the past year. Among the highlights, NASA and Boeing signed a $5.6 billion contract to build Space Station Alpha. The first incremental design review was held for Alpha.

An interim agreement was signed between NASA and the Russian Space Agency, bringing Russia more formally into the program.

The Shuttle/Mir program has begun. U.S. astronaut Norman Thagard is now aboard Russia's Mir Space Station. And NASA has built nearly 50,000 pounds of Alpha hardware.

Nevertheless, many challenges remain. Boeing has not signed contracts with its major subcontractors, Lockheed,

McDonnell Douglas, and Rockwell. "Aviation Week and Space Technology," a leading trade publication, says Space Station officials are struggling to overcome production delays and management missteps.

Russia is in the critical path, but the health of the Russian space industry is questionable. And the details of what Russia will provide at no cost to NASA are not yet finalized. Canada has cut back its contribution to the program, and the European Space Agency is reassessing its participation.

The wisdom of having Russia in the critical path, considering the political and economic instability there, and the tenuous nature of U.S.-Russia foreign policy, is a crucial issue, as is the question of whether or not the European Space Agency will decide in October to withdraw from the program.

However, these international issues have overshadowed questions about NASA's plan for building Alpha, and I would like to focus on those aspects now.

The question is whether Alpha can be built on schedule and for the cost NASA claims. If the schedule slips, costs will rise. There are two particular areas of schedule risk that I would like to highlight.

The first is the assembly sequence, which shows 44 launches in a 55-month time period. In addition to those launches, 10 more are needed to bring crews to the Station and 19 are needed to re-boost the Station to keep it at the proper altitude.

Hence, NASA is expecting 73 launches to take place on time and in sequence over 55 months. Of these, 27 or 28 are U.S. Space Shuttle launches that have 5-minute launch windows.

The assembly sequence has no room for manufacturing delays, launch delays or launch failures. Even under the best of circumstances, 73 on-schedule launches in 55 months by 3 different countries would be quite an impressive achievement. Is NASA's assembly sequence realistic? And what are the cost implications for the program if it is not?

The second issue is that of spacewalks, or EVAs (for extra-vehicular activity). The number of spacewalks needed to assemble Alpha rose significantly in the past year, from 434 to 888 hours, of which 648 are American EVA hours.

And NASA expects the number to grow as it becomes more familiar with the design. Just a year ago, NASA expected the number to decrease, not increase.

Heavy reliance on spacewalks increases the schedule risk, if they cannot be completed within the assigned time.

One question is whether NASA adequately understands the difficulty involved in these spacewalks to accurately estimate how many are required.

Many of the tasks for Alpha are more akin to what the Russians have been doing on Mir than what American astronauts have been doing on the Shuttle, and it is not clear that NASA has taken advantage of the Russian experience.

Other questions raised by the dramatic increase in space-walk hours are whether it is a signal of trouble with the Alpha design, how much the spacewalks will reduce the time the astronauts have to perform science, and why NASA so suddenly changed its philosophy about spacewalks from being a "last resort" to being an "opportunity."

Concern about the number of spacewalks dates back almost to the beginning of the Space Station program. And during the 1993 redesign, the Vest Committee concluded that Option B was the highest risk of the three options, specifically mentioning the large number of EVA hours needed, 311. This is much less than half of what is now expected for Alpha.

The Vest Committee said, "EVA is an inherent risk to crew safety, and such heavy dependence on EVA threatens the success of station assembly."

Why did NASA suddenly shift its philosophy about the risk involved?

When President Clinton ordered the redesign of the Space Station Freedom Program in 1993, two explicit objectives were "to greatly reduce the number of Shuttle launches required for deployment" and "greatly reduced the EVA requirements during deployment." The Alpha design does not meet those objectives.

As long as the Space Station partners are willing to continue to fund this program indefinitely, regardless of when assembly is completed and its ultimate price tag, schedule slips are not a problem.

For those seeking to place caps on funding or simply seeking to understand the total investment required, many questions remain.

Thank you.

Senator BURNS. Thank you. Again, your written statement will be made a part of the record.

[The prepared statement of Ms. Smith follows:]

PREPARED STATEMENT OF MARCIA S. SMITH

The Space Station Program: Progress and Challenges

Mr. Chairman, members of the subcommittee, thank you for inviting me here today to testify about the progress that has been made in the past year on the Space Station program and the challenges that remain. As you requested, my comments will focus more on the challenges ahead, and provide some comparisons between NASA's current International Space Station Alpha program and the Space Station Freedom program that preceded it (Freedom was terminated in 1993).

PROGRESS

In the past 12 months, the Space Station program has seen progress both domestically and internationally.

- NASA and the Space Station's prime contractor, Boeing, signed a $5.63 billion contract in January 1995 to build the Space Station. The contract, which runs through the year 2003, reflects NASA's new procurement philosophy of motivating contractors to avoid cost growth, and includes incentives for getting the job done for less than the "target cost" of $5.147 billion, as well as penalties ("negative fees ") if there are overruns.
- Lockheed and Russia's Khrunichev signed a $190 million contract for building the FGB module, the first piece of the Space Station scheduled to be launched. A Critical Design Review (CDR) also was completed for the module.
- The first Incremental Design Review (IDR) was held for the Alpha design.
- An interim Memorandum of Understanding was signed between NASA and the Russian Space Agency to bring Russia into the Space Station program.
- A definitive $400 million contract was signed between NASA and the Russian Space Agency. Of the $400 million, $335 million is for using the existing Russian Space Station Mir through the Shuttle/Mir program; the remaining $65 million is for work related to Alpha (including $25 million for early work on the FGB module, which is in addition to the Lockheed-Khrunichev contract).
- The Shuttle/Mir program has begun. NASA expects experience gained in working closely with the Russians on Mir to benefit cooperation on Alpha. An American astronaut, Norman Thagard is now aboard Mir, and a U.S. space shuttle is scheduled to dock with Mir and bring Thagard and his two Russian crewmates back to Earth in late June (the shuttle also will deliver a two-man Russian replacement crew). This will be the first docking of an American and Russian spacecraft in 20 years (the only other time this happened was the 1975 Apollo-Soyuz Test Project). Two Russians already have flown on the U.S. space shuttle (February 1994 and February 1995). On the second of those flights, the shuttle rendezvoused (but did not dock) with Mir.
- Russia and Kazakhstan have signed an agreement for Russia to lease the Baikonur Cosmodrome. Baikonur is the site used by Russia for all its Space Station-related launches (both for its existing Mir Space Station, and for Alpha). This may

provide some stability at the launch site and the city of Leninsk which services it, both of which have deteriorated since the collapse of the Soviet Union.

NASA has built 48,200 pounds of hardware for the Alpha program, including the exterior of the first node (a module that connects other modules, and where the shuttle will dock). By the end of the year, 75,000-80,000 pounds are expected to be completed, out of a total of 612,900 pounds that need to be built.

CHALLENGES

Despite the progress, major challenges remain for the Space Station program. These can be roughly divided into those that concern the design, schedule and cost of Alpha, and those that specifically concern the international partners. The past year has been one of relative stability for a program with such a turbulent past. Now the hard part begins—building it.

Alpha's Design, Schedule and Cost

- The assembly sequence (September 1994) is extremely ambitious. It shows 44 launches in 55 months (November 1997-June 2002), while another 10 launches are needed to take crews to the Space Station, and 19 more are needed for reboosting the Space Station's altitude during the same period. Hence, 73 flights are required to be conducted on time and in order over 55 months. By comparison, the final Space Station Freedom design required 20 space shuttle launches for assembly. (The Alpha numbers include 6 "utilization" flights, which must be subtracted from the total of 73 launches in order to compare with Freedoms 20 flights.). This issue is discussed in more detail below.
- The number of spacewalks (or "extravehicular activity"—EVAs) has grown, even though a year ago NASA had said it would reduce the number of spacewalks needed. NASA expects the number to continue to grow as it becomes more familiar with the design. In March 1994, the number was estimated at 434 hours, with 70-80 identified for deletion. By March 1995, the number had grown to 648 hours. Another 240 hours of Russian spacewalks also are required, for a total of 888 hours. By comparison, the final Space Station Freedom design required 365 hours of spacewalks for assembly. This issue is discussed in more detail below.
- Although NASA and Boeing have signed their contract with each other (5 months later than planned), Boeing has not yet signed contracts with its major subcontractors, McDonnell Douglas, Rockwell International, and Lockheed. Signing of these contracts had been expected in April.
- Operational costs continue to raise concerns, particularly with the international partners. During the 1993 redesign, NASA stated that operational costs would be $1.3 billion a year (annual operational costs for Freedom were estimated at $2-2.4 billion). The existing international agreements call for the partners to pay a share of the operating costs. These agreements are being renegotiated to bring Russia into the program, and, faced with their own budget constraints, the partners (particularly the European Space Agency—ESA) want to change the agreement so they can provide services (such as launches to bring cargo to the Space Station) in lieu of money. NASA reportedly is amenable to this proposal. Also, in March 1995, NASA Administrator Daniel Goldin told ESA he would cap common operating costs. The question is what happens if operating costs exceed that amount. If the partners provide services instead of money, NASA will have to fund whatever the operational costs are, including any that exceed the negotiated cap. (NASA is currently studying whether Space Station operations should be "privatized." What impact this would have on NASA or the other partners is unclear.)
- Aviation Week and Space Technology asserts that Space Station officials are "struggling to overcome delays in the production of critical components and management missteps that have strained the program's budget and schedule and tested the relationship among station team members." (May 8, 1995, p.60-61.) Among the problems were bad welds on the node (which were subsequently fixed); redesign of seals for hatches on the structural nodes in an attempt to improve them, but the result was raising the loads needed to secure the hatch beyond acceptable limits, so they had to be redesigned again; and delays in developing the common berthing module which, Doug Stone, Boeing vice president for the Space Station program, calls "the most critical piece of mechanical hardware we have to build early on in the program."

International Partners

- Russia is in the critical path for building the Space Station, but the health of Russian space industries raises concerns about whether Russia can fulfill its role.

These industries depend largely on government funding. The Russian space program has encountered funding problems much more severe than NASA faces today. In February, the heads of the Russian civilian and military space programs (Yuri Koptev and Gen. Vladimir Ivanov, respectively) said that if funding were not increased, the entire space program might end in 2–3 years. While this might be an exaggeration, the civilian space program now receives only 20% of what it did in 1989, while the military space program receives only 10% of its 1989 funding. According to the U.S. consulting firm, ANSER, for 1995 the Russian Space Agency (which conducts the civilian space program) has been allocated 1.8 trillion rubles by the Parliament, or $402 million at the March 1 exchange rate. This was a 50% increase over the agency's formal request of 1.2 trillion rubles (though in February, Koptev said he needed almost 3 trillion rubles), but the additional funding was to make up for a shortfall in 1994. Thirty percent of the 1994 funding allocated for the Russian Space Agency was not transferred to the agency by the Ministry of Finance, reportedly because it had to be used to support the war in Chechnya, according to ANSER. (This problem was not unique to the Russian Space Agency.) Lack of funding has called into question the viability of some Russian space industries, especially smaller companies providing component parts. Several Russian elements are critical to the Space Station's successful completion: the FGB module for guidance, navigation and control[1]; Soyuz spacecraft that are "lifeboats" for the crew in emergencies; and Progress M and Progress M2 spacecraft that are used to reboost the Space Station periodically to maintain the correct altitude (the Progress M2 does not yet exist). Another Russian module, the Service Module, serves as the crew quarters, with life support systems, kitchen, bathroom, and sleeping space, during most of the assembly period.

- The details of Russia's role are still being negotiated and what Russia will provide at no cost to NASA is not finalized. A new Intergovernmental Agreement (IGA) among all the partners at a governmental level, and individual Memoranda of Understanding (MOUs) between NASA and its counterpart agencies, are still under discussion. NASA expects to complete them sometime in 1995. NASA assumes that, with one exception (the FGB module), Russia will provide its hardware and services as a partner, on a no-exchange-of-funds basis, but that will not be finalized until the agreements are signed. Considering that the United States is paying Russia $335 million just for using the existing Space Station Mir, and $215 million for the FGB module ($25 million directly from NASA plus the $190 million in the Lockheed-Khrunichev contract), it may be premature to assume that Russia will not charge for anything else.
- U.S.-Russian political relationships have cooled somewhat, particularly because of the proposed Russian sale of nuclear reactors to Iran. The possibility that this U.S.-Russian relations could change markedly during the 18-year course of the Space Station program (1994-2012) is a definite risk. Also, though current debates about cutting foreign aid to Russia do not seem to include the $400 million NASA is paying the Russian Space Agency, that question could arise. Similarly, some might question whether the $400 million indirectly supports the war in Chechnya, enabling the Russian government to take money from Russian space activities to pay for the war and still maintain the space program.
- Canada has cut back its contribution to the program, and will not decide until 1997 whether to build the final portion of its robotic servicing system that will be used in assembling and maintaining the station. Canada is building the "arm", but has not decided on whether to build the Special Purpose Dextrous Manipulator (SPDM) that fits at the end of the arm (often referred to as the "fingers "). If not, NASA may have to build the SPDM at its own expense.

ESA is reassessing its participation in the program. A ministerial meeting where a decision will be made on what portions, if any, to build has been delayed until October 1995. ESA had been planning to build a laboratory called Columbus, an Automated Transfer Vehicle (ATV) that could be used to resupply the station, and a Crew Transfer Vehicle (CTV) for taking people to and from the station. The ESA Council recommended terminating the CTV at a meeting in March to reduce program costs, but France (one of ESA's major financial contributors) is still strongly interested in this part of the program.

[1]NASA lists the FGB module as an "American" component because it is being procured through a contract between an American company, Lockheed, and a Russian company, Khrunichev. Since the module is built in Russia by a Russian company, it is difficult to view it as anything but a "Russian" component, however. It is still subject to the same questions about the health of the Russian space industry and concerns about U.S.-Russian political relationships as the other Russian elements.

MAJOR ISSUES

Will the Other Partners Fulfill Their Roles?

Since the decision to bring Russia into the program in 1993, attention has focussed on the wisdom of putting Russia in the critical path on the Space Station program. Concerns about political and economic stability in Russia and the tenuous nature of U.S.-Russian relationships will undoubtedly plague the program for years to come. Even the political commitments of two of the original partners, Canada and ESA, is in question today. Only Japan's plan for the Space Station has remain unchanged over the years. (U.S. plans have themselves changed substantially over the past 11 years, so we are in a poor position to criticize our partners.)

The argument is often made that the United States cannot withdraw from the Space Station program because of its international commitments. Unquestionably, if the United States canceled the Space Station program it would have a chilling effect on future space cooperation, and perhaps on scientific cooperation more broadly. Nevertheless, the existing Intergovernmental Agreement allows any partner to withdraw simply by giving one year's notice and the United States is not the only partner who has thought about it. Canada intended to withdraw, but was convinced by the United States to downscale its contribution instead. ESA is considering whether or not to withdraw. Our partners clearly recognize that national priorities may change. They could decide not to participate, and so could the United States. International commitments are an important, but not necessarily a decisive, consideration.

Has NASA Developed an Executable Program?

In the past two years, these international issues have overshadowed other questions about the Space Station program. Assuming the best on the political front—that each partner fully funds the Space Station program, U.S.-Russian relations remain friendly, and Russia, Kazakhstan and Ukraine remain on good terms (Russia is the Space Station partner, but Russia needs the other two former Soviet republics to accomplish its role)—there is still the question of whether Alpha is an "executable" program. Can it be built on the schedule and for the cost NASA claims?

Two cost issues already have been described—whether NASA will have to pay to build Canada's SPDM, and whether NASA might have to pay additional monies to Russia. Perhaps of greater concern is the schedule, however. Schedule and cost are inextricably connected—if the schedule slips, the costs will rise. Thus the question is whether the assembly sequence NASA has laid out is realistic and whether the number of spacewalks can be accomplished on schedule. (There are other issues about the number of spacewalks, too, discussed below.)

The Assembly Sequence

The most recent assembly sequence for the Space Station released by NASA is from September 1994. It shows 44 launches in a 55-month time period. These include 6 "utilization flights." In addition, 10 launches are needed to bring crews to the station and 19 launches to reboost the station to maintain the proper altitude. Hence, NASA is expecting 73 launches to take place on time and in sequence over 55 months. Of these, 27-28 are U.S. space shuttle launches that have 5 minute launch windows (they must be launched within 5 minutes of their scheduled time or wait until the next day); 1 is European; and 44 are Russian using a variety of launch vehicles (some of which are built in Ukraine) launched from the Baikonur Cosmodrome in Kazakhstan. (The launch vehicle for one component is not yet determined, hence the uncertainty in U.S. shuttle launches.)

As recent experience with the Shuttle/Mir program demonstrates, this will not be an easy task. Russia had repeatedly delayed the launch of a module intended to dock with Mir, called Spektr. Since Spektr carries a number of American experiments that were to be used by U.S. astronaut Norman Thagard during his March-June visit to Mir, the plan was to have Spektr in place before his arrival. However, the Russians delayed the launch of Spektr from February until early May and then to late May. Hence, Thagard has been aboard Mir since March unable to do much of the research he planned to do (although some of his experiments were brought to the Space Station by another spacecraft). Spektr was finally launched successfully three days ago (May 20) and had been scheduled to dock with Mir this Saturday, but the docking reportedly has been delayed until June 1 because of unexpected changes to the spacewalk schedule in preparation for Spektr's arrival (see below). This is the fourth module sent to Mir, and none of the others docked on the first

try—but each did dock eventually. The Russians need approximately one month to get Spektr into the correct position on the Space Station and check that it is working properly.

To allow for the slip in Spektr's launch date, NASA had to reorder space shuttle launch dates, since a shuttle mission intended to dock with Mir and return Thagard and his crewmates to Earth (and bring a new Russian crew to Mir) was planned for early June. Now a different shuttle mission will be launched in early June and the Mir docking mission will take place later that month. (Whether the reported delay in Spektr's docking date will also affect the space shuttle schedule is unclear.) This flexibility in swapping launch dates will not be possible in the Alpha program since each flight brings up a specific piece of hardware that must be attached to other pieces in a particular order.

Looming over every space launch vehicle is the possibility of a launch failure. In the case of expendable launch vehicles (ELVs), the Space Station component would be lost and it would probably take months to determine and resolve the cause of the failure before the launch vehicle would be recertified for flight. In the case of the space shuttle, where loss of life might also be involved, it would certainly take much longer (it was 32 months in the case of the Challenger tragedy). And a replacement component would have to be built for whatever was lost in either an ELV or shuttle accident.

The assembly sequence has no room for manufacturing delays, launch delays, or failures. Even under the best of circumstances, 73 on-schedule launches in 55 months by three different countries would be an impressive achievement. Is NASA's assembly sequence realistic and what are the cost implications for the program if it is not?

Spacewalks

As already discussed, the number of spacewalks needed to assemble Alpha rose significantly in the past year—from 434 hours to 648 hours, plus another 240 hours of Russian spacewalks—and NASA expects the number to grow as it becomes more familiar with the design. NASA had said in March 1994 that it expected the number of hours to decrease, not increase.

Heavy reliance on spacewalks increases the schedule risk if they cannot be completed within the assigned time. If they are not, the schedule will slip and costs will increase. Apart from the issue of familiarity with the Alpha design that NASA itself notes, the question is whether NASA has an adequate understanding of the difficulty involved in the spacewalks needed for Alpha to accurately estimate how many hours are required. NASA believes its experience with spacewalks on space shuttle missions, particularly repair of the Hubble Space Telescope, provides sufficient experience to estimate the hours and level of difficulty. As complicated as the Hubble repair mission and others have been, though, many of the tasks for Alpha are more akin to what the Russians have been doing in repairing and reconfiguring the Mir Space Station.

For example, one of the early tasks for Alpha will be relocating a solar array (which generates electricity) and its radiator which will involve disconnecting and moving those large masses and reconnecting them elsewhere on the station. This is not unlike a task the Russians have been pursuing for the past four years to move two solar arrays from one module (Kristall) to another (Kvant). As currently positioned the arrays would interfere with the docking of other Space Station modules (including Spektr, discussed above) and the space shuttle.

So complicated is this effort that the Russians apparently have now decided to move only one of the two, and leave the other one where it is, but folded up. Even moving the one array has been more difficult than expected. After a number of spacewalks since 1991, the cosmonauts are finally accomplishing the last step of the process now. The cosmonauts conducted two spacewalks (May 12 and May 17), each exceeding the scheduled amount of time, but still were unable to complete the task. An extra spacewalk had to be scheduled (and was to take place yesterday, May 22). The maxim of "whatever can go wrong, will go wrong" certainly applies to spacewalks. Despite the ready accessibility of Russian cosmonauts these days, it is not clear that NASA has taken advantage of the Russian spacewalk experience in assessing the level of difficulty and thus how many hours of spacewalks will be involved in building Alpha even though it may be more relevant than what American astronauts have done.

The rise in the number of spacewalks involves other issues, too. First is what it says about the design maturity of Alpha. NASA says it still is not certain of the exact number of hours, not because of the level-of-difficulty questions just discussed, but because they are still becoming familiar with the Alpha design. One must won-

der what is happening with the Space Station design that the number of spacewalks has risen so dramatically in just one year, and whether this is harbinger of trouble ahead. Design immaturity can lead to surprises that also will impact schedule and cost.

Second is NASA's sudden change in philosophy about the risk involved in spacewalks. No longer does NASA consider spacewalks a "last resort"; now they are an "opportunity." Concern about how many spacewalks are involved in Space Station construction date back almost to the beginning of the Space Station program. In 1986, following the Challenger tragedy, the NASA astronaut office insisted on having a greater role in the design of the Space Station and reportedly complained in particular about the large number of spacewalks needed for assembly—670 hours (similar to what is needed today for Alpha). Concerns reached their peak in 1990 when estimates of maintenance (not assembly) spacewalks reached 5 per week. For this and other reasons, Congress directed NASA to restructure the Space Station program at that time. (The restructured program reduced maintenance spacewalks to 1 every 8-10 days for Freedom. NASA estimates the number of maintenance spacewalks for Alpha at 1 every 25 days.) During the 1993 redesign, the Vest Committee (appointed by Vice President Gore to oversee NASA's efforts) concluded that "Option B" was the highest risk of the three options, specifically mentioning the large number of spacewalk (or EVA) hours needed—311 hours for assembly, 187 hours per year for maintenance. The committee's report said "EVA is an inherent risk to crew safety, and such heavy dependence on EVA threatens the success of station assembly" (page 47). With the long-standing concern about number of EVA hours, it seems surprising that NASA would so suddenly shift its philosophy about the risk involved—both to the astronauts and to the schedule.

Third, if the astronauts are busy conducting spacewalks, it reduces the amount of time they can spend performing science, the reason the Space Station is being built. The number of hours does not include, for example, the "pre-breathe" hours the astronauts must spend in their suits prior to exiting the space shuttle or Space Station to avoid the bends. With those hours added, and only 3 crew members aboard the Space Station for most of the assembly period (though some spacewalks will be done by visiting space shuttle crews), the amount of scientific research will be reduced. (Another factor is that with the constant arrivals and departures of American and Russian spacecraft, the "quiet" microgravity environment will be degraded, negatively affecting what science can be accomplished.)

SUMMARY

In summary, for every step of progress in the past year, at least one challenge remains. Although international issues are receiving greater attention these days, real questions exist about whether this Space Station can be built on the schedule and for the cost that NASA currently claims.

In many ways, Alpha is more complex than Freedom. In fact, when President Clinton ordered the redesign of the Space Station Freedom program in 1993, two explicit objectives were to "greatly reduce the number of shuttle launches required for deployment"[2] and "greatly reduce the EVA requirements during deployment." The Alpha design does not meet either of these objectives. The number of shuttle launches specifically for assembly is almost the same (20 for Freedom, 21-22 for Alpha), and the number of spacewalks is much higher (365 for Freedom, 888 for Alpha including American and Russian spacewalks). And 44 Russian launches and one European launch have been added.

As long as the Space Station partners are willing to continue to fund this program indefinitely, regardless of when assembly is completed and its ultimate pricetag, schedule slips are not a problem. For those seeking to place caps on funding, or simply seeking to understand the total investment required for building the Space Station, many questions remain. For all the challenges the Space Station has survived, many more await it.

[The biography information provided with prepared statement is maintained in subcommittee's file]

Senator BURNS. The Space Station is budgeted at $2.1 billion a year through fiscal year 2002, with an expected total cost of $30 billion.

Given the tendency of Space Station and other large NASA programs to experience substantial cost overruns, I would like to ask

[2]Mar. 9, 1993 memo from the NASA Administrator to Officials-in Charge of Headquarters Offices; Directors, NASA Field Installations; and Director, Jet Propulsion Laboratory.

this panel: Do you believe that this budget baseline will hold, or do you think it will escalate?

And I would start with you, Ms. Smith.

Ms. SMITH. As I have outlined in my testimony, I think that there are concerns about the schedule. And if the schedule slips, the costs will rise. So I think that there are legitimate concerns about whether or not the Space Station can be built for the cost that NASA is currently claiming.

There also are other costs associated with the Space Station program that are not included in that category in the NASA——

Senator BURNS. Can you pull that microphone just a little bit closer to you?

Ms. SMITH. There also are costs associated with the Space Station program that are not included in the Space Station line item.

They are the costs for modifications of the Space Shuttle, including a new external tank, as well as the costs of the $400 million Russian contract that are not included in those Space Station cost estimates.

Senator BURNS. And you say that even though Boeing has signed the contract with NASA as being the primary contractor, no subcontractor contracts have been signed.

Ms. SMITH. The subcontractors—the McDonnell Douglas,

Lockheed and Rockwell contracts, have not been signed.

Senator BURNS. Mr. Rogers, do you want to make a comment on that question? Do you think we can hold the baseline, or do you think it will escalate?

Mr. ROGERS. I am not sufficiently close to the present program circumstances, Mr. Chairman. They are under taking a very, very complicated activity here and working at it very hard. I am assuming that it will be constructed in a reasonable amount of time at an acceptable cost, whatever that may be.

What I am saying is that, with that assumption, we should now begin to think of the payoff of the station because if we do not appreciate its great potential economic value, then if we do begin to encounter additional costs, we may not look at that situation appropriately. We may not look at it in a balanced fashion.

I have had responsibilities for bringing government programs into being and private sector programs into being. Life is complicated. We will have to just wait and see.

Senator BURNS. With that, with those two comments,

Dr. McPherson, I will direct this one to you. Big science projects, in your opinion—and some folks would say that the cost of those big projects are too much for one country, for one country to do, that it takes a partnership between different nations.

If that is true, is it more important than ever that the U.S. honor its commitments to foreign partners on a joint science project such as the Space Station, and especially in the area of research?

Dr. MCPHERSON. I think any enterprise requires a principal investor, a leader, and I think the United States is clearly the only nation in the world today that could possibly provide that leadership.

I certainly believe that it is to everyone's advantage to include as many international partners as one possibly can in this enter-

prise, not only for political and economic reasons, but also, I think, to optimize the science output of this Space Station.

In our own laboratory at the University of California——

Riverside, we have collaborations with German, French and Spanish scientists. We have collaborations with Japanese scientists, and we have collaborations with Canadian scientists as well.

All of these scientists are eager to participate. They encourage their own governments to participate as much as they can. And I think we should take advantage of what you might call grassroots scientific support around the world here for a Space Station.

I think there always are some concerns on the part of the Europeans, less so on the part of the Japanese, about the cost of Space Station, but I do not see any reduction or any loss of enthusiasm among the scientific communities or the populace in general of those countries for Space Station and space science.

Senator BURNS. Senator Pressler.

The CHAIRMAN. Yes.

Ms. Smith, I understand you have been to the Space Center in Kazakhstan, which is the site where the Russian Space Station Alpha launches will take place. Would you describe your impressions of that site?

I understand that your visit left with you many concerns about the Russian launch infrastructure you observed there. And will you share with the subcommittee what those concerns are?

Ms. SMITH. Regrettably, Senator, I have not been to the Baikonur Cosmodrome in Kazakhstan, but I would be delighted to go if the committee would like to send me.

The CHAIRMAN. OK. [Laughter.]

Ms. SMITH. I have heard a lot of stories from colleagues who have been to Baikonur. Baikonur is a large geographic area that includes the launch site and the city of Leninsk that services it.

And there has been long-standing concerns since the collapse of the Soviet Union, particularly about the city of Leninsk, where the workers of Baikonur live. And those conditions are really quite dreadful.

In fact, there are quite a few Western journalists who were in Leninsk in March for the launch of American astronaut Norman Thagard when he went up to Mir. And there was a front page story in The New York Times that detailed just how bad the living conditions are there.

As for the launch site, the launch site is still a functioning spaceport. In fact, Russia, as a country, continues to launch more often than anyone else in the world.

They have two launch sites, the one at Baikonur and another one that is actually in Russia.

So the conditions there are not as good as they used to be, but it is still a functioning spaceport. The question is whether or not it will be provided with adequate financial resources so that during the course of the Space Station Alpha program, it will continue to be able to perform its function.

The CHAIRMAN. So even though Russia is funding this, it is a foreign country from which they are launching.

Ms. SMITH. Exactly. Kazakhstan is now an independent country, separate from Russia. And an agreement has been signed between Russia and Kazakhstan for Russia to lease the Baikonur Cosmodrome for 20 years with an option for 10 more at a cost of $115 million a year.

That has to come out of the Russian Space Agency's budget. Not all of it has to be in cash. Some of it can be in services, but it is a large amount of money. The Russian Space Agency's budget is about $400 million.

So this is a large sum of money. And the question is whether or not they will have additional money to actually maintain and upgrade the facilities at Baikonur, in addition to the lease.

The CHAIRMAN. Yes. I traveled out there about 2 years ago. And my observation was that we were on very shaky grounds there, because if—just the whole infrastructure struck me as being not very good, to put in mildly. And the system of supply, the system of being able to travel there, just—there are just problems waiting to happen.

Are there other launch sites Russia has that would be better?

Ms. SMITH. Russia has one other launch site called Plesetsk, which is within the borders of Russia itself. But it is too far north to service the orbit that they are going to be using for the Space Station.

In fact, the Space Station orbit was chosen because it is accessible from the Baikonur Cosmodrome, as well as from Cape Canaveral.

The CHAIRMAN. Now, the current NASA space program began in 1984. Would you compare the capabilities of the current Station Alpha with NASA's 1984 Station? Would it be fair to say that with Alpha, we get much less in capability, but far more money in complexity than we originally planned for?

Ms. SMITH. The Space Station program—it was not named Freedom at the time it began in 1984—was a very, very, very different program from what we have today. That program was redesigned five, six or seven times, depending on how you count redesigns.

And I would have to provide you for the record information about a comparison from the original 1984 design until today's Alpha's design.

Most of the comparisons that NASA makes are between this version of Alpha and a previous version of Alpha that existed briefly in September 1993. And then if you look a little further back, you can compare it with the final Freedom design that existed in 1993.

The CHAIRMAN. When I visited there, there was strong local feeling against Russians, the Russian language and so forth, forcing the local government to function in the local language. Does this cause any problems?

Ms. SMITH. I am not aware of any problems in that regard.

The CHAIRMAN. OK. Now let me ask this question of mega science projects versus smaller science projects. There seems to be two schools of thought.

We have a huge scientific project like the Space Shuttle, or we have a huge project like the great physics project that was going to be in Texas versus spending money on smaller scientific research.

Is there a split—and maybe Dr. McPherson, you have already alluded to this. But are there two schools of thought on this?

Do we get more real research product out of mega scientific projects, such as the Super Conductor, Super Collider or the Space Shuttle, or do we get more from what we call minor research?

Dr. MCPHERSON. Well, first of all, I would say that there is some science that can only be done in terms of mega science. There are certain experiments that could only be done with the Super Collider. There are certain experiments that can only be done if we have an orbiting Space Station.

So I do not—yes, there is some division according to size, but I think it is fair to say that by excluding completely these mega science projects, you are going to be excluding a good part of science, important science as well.

In addition, mega science projects provide opportunity for many, many, instances of smaller science to be performed. Remember that the Space Station is designed to provide for laboratory science.

It is not the traditional NASA observational science that we are talking about here. We are talking about laboratory type of experiments that have to be carried on over and over again with great repetition. Reproducibility is a major concern here.

And we can only get that opportunity, we can only provide that environment, if we have a long duration facility in microgravity to carry out that research.

So I do not think the two are mutually exclusive. In fact, there is a continuum there.

The CHAIRMAN. Do the rest of you have any opinions on that?

Now, Dr. McPherson, you have already alluded to this.

Under current plans, Space Station Alpha will receive a large centrifuge for life sciences research in 2004.

What would this piece of equipment do for microgravity research on the Space Station once it begins to operate? Do you agree that an operating large centrifuge will make any microgravity research next to impossible to conduct?

Dr. MCPHERSON. No. By no means is that the case. I think we can easily carry out the microgravity research in the presence and the operation of the centrifuge. That is not a concern.

The centrifuge, we hope, will in fact contribute to microgravity research in the sense that many experiments need to be carried out not only at zero gravity or microgravity, but in increments between one G and zero gravity or microgravity.

The centrifuge will allow us to conduct real microgravity research at those incremental levels between 10–6 and 1. For example, combustion experiments need to be evaluated at not only 10–6 and 1 G, but they need to be evaluated at those increments in between.

So in fact, it is our view that the centrifuge may in fact contribute to microgravity research.

The CHAIRMAN. My final question could be taken by anybody. It seems we are sort of in a water torture process here with the Space Shuttle.

We are kind of torturously going along with all these cuts, which are necessary under our budgetary situation, but we have probably reached a point where all the fat is out of it.

And maybe we are being self-destructive at struggling along year after year trying to keep the idea alive.

What would be your recommendation?

How should we, as policymakers, do this? Should we make a decision to really do it, or are we on the right track with this kind of struggling along each year, or should we just cut it off if we are going to keep doing that?

Dr. MCPHERSON. From the standpoint of the scientists who intend to use Space Station, it would be of great benefit to us if this issue of Space Station were decided once and for all and a commitment were made to go ahead for multiple years, so that we did not have to go through this battle every year in the Congress to preserve it once again.

This year-to-year process makes it very, very difficult in terms of engineering and science planning. And I think indeed the Congress should make a decision that yes, we are going to do it, or no, we are not. And you are absolutely correct. Let's turn off the water torture.

Ms. SMITH. If I could respond as well? I think the Congress has decided year after year to continue to fund the program. We have said in our testimony we do support multi- year authorization. But beyond that, it is not unreasonable to review the program.

In response to Senator Burns's first question, however, the best way to assure that this program is over budget is to stretch it out and to continue to cut back at it in small ways. It needs to be fully funded.

I think that the program so far can be developed. The best way we have to provide an incentive to this NASA and industry team, that it will continue to be running on budget and within the time allotted, is that they recognize the program is under such scrutiny in Congress that it will be canceled if it does not come in on budget and on schedule.

Mr. ROGERS. Let me say one thing, also, Mr. Chairman. I have run activities when I have said the following: You are never welcome to come into my office and tell me what I can get.

You are never welcome to come into my office and tell me what it is going to cost me. You are always welcome to come into my office and tell me what I can get for what I have.

You must look at both what you are paying and what you are getting at the same time. And one thing I have tried to do this morning is to suggest that we are getting to the point now in the space living quarters and the space transportation development where we can begin to think of large economic payoffs; not the payoff only of the Space Station itself, with its internal capabilities, but acting as a centerpiece, acting as an institutional and physical site that will be supported by commercially derived space transportation vehicle fleets that flow from the X–33 and the X–34 programs.

We can begin to see unit costs coming down within a decade or so, perhaps in some cases more rapidly than that, by a good factor of ten and, as I said, with a large enough market, a good factor of a hundred.

So I would urge you, when you consider paying the continuing costs and even some indeterminacies in the actual value of those

costs, that you look—you ask yourself again: What are we going to gain from the expenditure of that money?

The CHAIRMAN. Thank you very much, Mr. Chairman. If I have some additional questions for the record, I will submit them. Thank you.

Senator BURNS. I would notify you that you will probably get some written questions. And if you could respond to the individual senator and to the committee, we would certainly appreciate it. Dr. McPherson, I only have one question and then I want to recognize Senator Lott.

The first phase of the Space Station program involves conducting the experiments with the Russian Station Mir. Does Mir have a suitable environment for conducting world-class experiments?

Dr. MCPHERSON. Mr. Chairman, I do not think we know the answer to that at this time. We have very little record of the Russian experiments, microgravity experiments, that have been conducted up to this point that we can base a judgment on.

I think we will know far more when Astronaut Thagard returns in June and when some of the data is interpreted, and we have a much better picture of the microgravity environment there.

I think right now we are still indeed uncertain as to the quality of that environment. But I think the resolution of that will be very soon.

Senator BURNS. Senator Lott, thanks for joining us this morning.

STATEMENT OF SENATOR LOTT

Senator LOTT. Thank you, Mr. Chairman.

I just want to thank the witnesses for their testimony. I have been reading over it and following the hearing. Thank you.

Senator BURNS. We will excuse this panel and hear from the NASA folks, and we will probably get comments on your comments.

Thank you for coming this morning, and there again, if there are written questions to each one of you, why, if you will respond to both the Senators and the committee, we would certainly appreciate that. Thank you for your testimony this morning.

Senator BURNS. The next panel is Dr. J. Wayne Littles, the Associate Administrator of the Office of Space Flight, NASA, and Dr. Harry Holloway, Associate Administrator, Office of Life and Microgravity Sciences and Applications, for NASA.

Dr. Littles, it is good to see you again. We are probably going to get to be very good friends before we get through this.

Dr. Holloway, we want to welcome you to the committee this morning.

There again, if you want to shorten your statement, your written statement will be made a part of the record, and we appreciate your attendance this morning.

Dr. Littles, please proceed.

STATEMENT OF J. WAYNE LITTLES, ASSOCIATE ADMINISTRATOR, OFFICE OF SPACE FLIGHT, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION ACCOMPANIED BY: RANDY BRINKLEY

Dr. LITTLES. Mr. Chairman and members of the subcommittee, I am pleased to be here today to discuss the status of the inter-

national Space Station program. This is, of course, my first opportunity to appear before the committee and discuss the Space Station. I am proud to say that we have made significant progress since last year.

I believe we have kept our key commitment that we made to Congress last year to meet all of our major program milestones.

As has already been mentioned in testimony this morning, you can put hands on the progress we have made. In this point in time, we have manufactured over 48,000 pounds of hardware, and by the end of this year, that will be 75,000 pounds.

Of course, you can see our progress as well. During STS- 63, which flew earlier this year as a part of the Phase One Space Station program, the Space Shuttle Discovery rendezvoused with the Space Station Mir for the first time, approaching within 37 feet.

To achieve this rendezvous, teams of engineers and flight controllers in the United States and in Russia coordinated, clearly demonstrating one of the primary objectives that we set out to accomplish on Phase One, which was to establish and demonstrate working relationships with our Russian partners.

And that is well underway.

Of course, STS–63 was laying the groundwork for STS–71, which is going to fly in June. And that will be the mission where we first dock with Mir and exchange crews, and conduct some scientific investigations at that point in time.

Perhaps most important of all, our progress is measured by our management of the program. We have enacted the management and technical changes that were brought forth in the 1993 redesign.

As has already been mentioned, we have concluded negotiations with Boeing this year, and that was a significant and major achievement. And Boeing is in the final stages of negotiation with the product groups.

Although we have a number of issues that are being resolved, I feel that we are on track, and we will be successful in meeting the challenges ahead.

The Space Station's performance last year demonstrated clearly that our team of civil servants contractor and our international partners are committed and capable of going forward with the development and assembly of the international Space Station, and we are on schedule to do so.

All of our milestones, as important as they are, lead us to a single critical goal, and that is the fully operational status of the international Space Station.

As you know, the basic mission for the Space Station is, and has always been, to provide a world-class orbiting laboratory for conducting high-value scientific research and engineering in a microgravity environment.

In order to take advantage of the Space Station's capabilities as soon as possible, we are working hard with the user community to maximize their access to station resources during the assembly sequence.

We are in the final stages of developing a complete utilization plan for the Space Station, and we will be happy to share that with the committee when its finalized.

I know there has been concern, and we have heard some of that discussed this morning, over Russia's role in the Space Station program.

As we reported last year, the decision to include Russia as a full partner enabled us to build a much more capable station than we had with the Freedom design.

We have nearly twice as much power and volume, and 50 percent more crew, and those resources are going to allow us to do much more science, and we are doing that on an accelerated schedule, launching 15 months earlier than we would have, and with a savings of approximately $2 billion to the taxpayers.

And none of this has changed. To this point in time, the Russians are proving to be very valuable partners. However, recognizing the fact that something could happen, we are developing comprehensive contingency plans to allow the program to continue in the event of Russia's partial or complete withdrawal from the program.

The Russian Space Agency has received full assurance from the highest level of the Russian government that it will be provided all the resources needed to fulfill its obligations to the Space Station program.

Their launch infrastructure is being demonstrated to be sound as well. The Baikonur launch site, which is where all the Russian human space flight launches originate, had a perfect 30 for 30 record during 1994.

We have ever reason to believe that Russia will maintain its present involvement and contributions to the Space Station program.

I also know that there has been concern over the European Space Agency's role in the international Space Station. We have every reason to believe that ESA will continue its important participation in the program, and we are working closely with ESA as they move toward the October Minsters' meeting in defining their exact contributions to the program.

Our other partners are moving forward as well. The Canadian Space Agency recently completed its streamlining efforts, and the international Space Station remains a high priority in the CSA budget.

And the Japanese space agency, with the full support of the Japanese government, continues its strong commitment to the Space Station and is moving forward with the development of its hardware contributions.

Our international partners are deeply committed and involved in the program. As has already been mentioned this morning, they have expended over four billion dollars to date in development of the Space Station, and we remain very confident that all of our partners will move forward with us in the program.

Our international relationships are important to more than just the Space Station program itself. The nature of the Space Station program presents exciting opportunities for commerce and research opportunities to U.S. industry and academic institutions.

The program's basic concepts of sharing design, development, operations and utilization of the Space Station have provided and will continue to provide opportunities for international collaboration between governments, industries, scientists, and universities.

We have full confidence that the program is achievable.

We are developing an international Space Station that will be a world-class microgravity laboratory.

It provides the United States an opportunity to maintain its preeminence in space, while serving as a hallmark in international cooperation. With your continued support, we believe that we will be successful in this historic undertaking.

Thank you for the opportunity to appear here today. I would like to present my written testimony for the record, and I will be happy to answer any questions.

Senator BURNS. Thank you very much, Dr. Littles.

[The prepared statement of Dr. Littles follows:]

PREPARED STATEMENT OF DR. J. WAYNE LITTLES

Mr. Chairman and Members of the Subcommittee:

I am pleased to be here today to discuss the status of the international Space Station Program. This is my first opportunity to appear before this committee to discuss the Space Station, and I am very proud to say that we have made significant progress since last year. I believe we have kept the key commitment we made to Congress last year—to meet all of our major program milestones.

As we appeared before various committees last year, we were still fresh out of the 1993 redesign effort. Our Program Office had been moved to Houston, hosted by the Johnson Space Center, and we had selected a single prime contractor. Russia had been invited to join the international partnership, and we were just getting started in a new way of doing business within the Program and within NASA. However, this new environment did not mean we were any less accountable for our actions, nor did we shrink from our responsibilities.

PROGRAM MILESTONES

During the summer of 1994, we concluded a $400 million contract with RSA, which, in part, detailed Phase I of the international Space Station program. We have already seen major successes in Phase I. In February of this year, during STS-63, the Space Shuttle Discovery rendezvoused with the Russian Space Station Mir, approaching to a distance of 37 feet. This highly successful mission demonstrated that we can work well with the Russians and lays the groundwork for the historic STS-71 docking mission coming up next month.

What was especially exciting about STS-63 was the teamwork between U.S. and Russian engineers and technicians. When a leaking thruster on the Shuttle threatened the rendezvous, joint U.S./Russian teams worked in real time across the globe to find a solution to the problem—this clearly demonstrated that we can work effectively with Russia, just as we will continue to do during the remainder of Phase I and assembly and operation of the international Space Station. More exciting developments are only weeks away—as part of this upcoming historic docking mission, U.S. astronaut Norm Thagard, who will have spent the last 3 months aboard Mir, will transfer from the Russian Space Station and return to Earth aboard the Space Shuttle Atlantis. He will have set a record for time spent on orbit by a U.S. astronaut.

While Phase I has been underway, progress on the international Space Station program has moved rapidly forward. We have made major progress in producing hardware—by the tens of thousands of pounds in 1994 and 1995 alone. As of last month, over 48,000 pounds of hardware had been produced since early 1994. By the end of 1995, we will have over 75,000 pounds of hardware built. The exterior structure of one major piece of hardware, the Node Structural Test Article, was completed in early April. This Node will be refurbished and flown as Node 2 in September 1999. Node 1, the first U.S. element launched to the Space Station, is ahead of schedule in the manufacturing process and is scheduled for launch in December 1997.

In January 1995, we concluded negotiations with Boeing for the international Space Station prime contract. Not only does the contract include unique fee structures and cost-sharing provisions that have received praise both inside and outside of NASA, but the final contract cost came in at $5.638 billion—$570 million less than our not-to-exceed cap established with Boeing in August 1994. Boeing is now very close to completing negotiations with their subcontractors.

In early February of this year, soon after definitization of the prime contract, negotiations between Boeing, Lockheed, and Khrunichev and protocols between the Russian Space Agency (RSA) and NASA successfully defined the requirements for delivery of the Functional Cargo Block, or FGB, which is the first element of the Space Station. The Space Station program continues to successfully meet milestones leading to an on-schedule First Element Launch in November 1997.

In late March, we concluded the first of six Incremental Design Reviews (IDR). At this IDR we took a comprehensive, integrated look at the each of the systems and elements of the Space Station for the first six U.S. and five Russian flights and evaluated their progress. The major purpose of the IDR was to ensure that all elements are on track and that any conflicting integration and design issues have been or are being resolved. Literally thousands of issues were resolved during the culmination of six months' work. The remaining issues are being aggressively pursued through an issues meeting being conducted now by the Program Office in Houston. Resolution plans and impacts of those issues will be developed following the issues meeting.

Although we have a number of issues being resolved, I feel that we are on track and will be successftil in meeting the challenges ahead. The Space Station program's performance in the last year has demonstrated clearly that our team of civil servants, contractors, and international partners is operating at a high level of efficiency and is enthusiastically committed and capable of going forward with the development of the international Space Station.

UTILIZATION

All of our milestones lead us to a single critical goal—the fully operational status of the international Space Station. As you well know, the basic mission for the Space Station is, and has always been, to provide a world-class orbiting laboratory for conducting high-value scientific research and engineering in a microgravity environment. In order to take advantage of the Space Station's capabilities as soon as possible, we are working hard with the user community to maximize their access to Station resources early in the assembly sequence.

The Space Station program has the difficult task of balancing the needs of the research and engineering communities within the scheduled resources available for assembly. We have provided six flights during the assembly phases dedicated chiefly to utilization, and we are in constant contact with the user community to discuss their needs and requirements. The Research Management Office, located at the Space Station Program Office in Houston, works on a daily basis with program engineers and staff to ensure our lines of communication are kept open. Even now we are in the final stages of developing a complete utilization plan for the Space Station, and I will be happy to share it with the committee when it is finalized. We feel that we are fulfilling our commitments to the user community.

RUSSIAN ROLE

I know there has been concern over Russia's role in the Space Station program. As we reported last year, the decision to include Russia as a full partner enabled us to build a much more capable Space Station, with nearly twice the power and volume and 50% more crew—all on an accelerated assembly schedule and approximately $2 billion savings to taxpayers. None of this has changed. The Russians are proving to be very valuable partners.

However, we are developing comprehensive contingency plans to allow the program to continue in the unlikely event of Russia's partial or complete withdrawal from the program. Without a doubt, much of the savings in time and money brought about by Russian participation would be lost in the event of their withdrawal—let's be clear about that. That makes it all the more important for us to work with them to successfully sustain their participation, while at the same time to prepare contingency plans should they withdraw. We have done both, and will continue to do so.

The Russian Space Agency (RSA) has received full assurances from the highest levels of the Russian government that it will be provided all of the resources needed for it to fulfill its obligations to the Space Station program. Their launch infrastructure is sound as well—the Baikonur launch site, from which all Russian human space flight launches originate, had a perfect 30 for 30 launch record in 1994. We have every reason to believe that Russia will maintain its present involvement and contributions to the Space Station program.

INTERNATIONAL PARTNERS

I also know that there has been concern over the European Space Agency's role in the international Space Station. Let me be quite clear—we have every reason to believe that ESA will continue its important participation in the Space Station program. We are working very closely with ESA to determine their exact contributions to the program.

Our other partners are moving forward as well. The Canadian Space Agency recently completed its streamlining efforts, and the Space Station remains a high priority item in the CSA budget. And the Japanese Space Agency, NASDA, with the full support of the Japanese government, continues its strong commitment to the Space Station and is moving forward with development of its hardware contributions.

Our international relationships are important to more than just the Space Station program—the nature of the Station program presents exciting collaborative commercial and research opportunities to U.S. industry and academic institutions. The program's basic concepts of sharing design, development, operations and utilization of the Space Station have provided the opportunities for international collaboration between governments, industries, scientists and universities.

Our international partners are clearly deeply involved in the program—they have expended over $4 billion to date in development of the Space Station—and we remain very confident that all of our partners will move forward with us in the program.

CONCLUSION

The Space Station program has, I believe, fulfilled its commitments to Congress and the American people during the past year. We are prepared to commit to you once again that we will meet or exceed all of our major program milestones this year.

The international Space Station is on-schedule and on-budget. As you have seen in the past year, the Space Station program has demonstrated a new way of doing business, and NASA is committed to continue on that path. In order for us to fulfill our commitments and maintain this level of progress, though, it is essential that our funding remain stable.

We have full confidence that the program is achievable—but we must maintain our current funding levels. We are developing an international Space Station that will be a world-class microgravity laboratory. It provides the United States an opportunity to maintain its preeminent role in space while serving as a hallmark in international cooperation. With your continued support we will be successful in this historic undertaking.

Thank you for the opportunity to appear before you. I would welcome any questions that you may have.

Senator BURNS. Dr. Holloway.

STATEMENT OF HARRY C. HOLLOWAY, ASSOCIATE ADMINISTRATOR, OFFICE OF LIFE AND MICROGRAVITY SCIENCES AND APPLICATIONS, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Dr. HOLLOWAY. Mr. Chairman and distinguished committee members, I am pleased to have the opportunity to appear before this subcommittee and report on NASA's plans for conducting the U.S. program of science, technology, engineering, and commercial research aboard the international Space Station.

My office, the Office of Life and Microgravity Sciences and Applications, is responsible for selecting and supporting experimental research in the life and physical sciences.

This research is currently conducted aboard the space shuttle, the Russian Mir Space Station, and uncrewed spacecraft.

We will also select, support, and manage experimental research aboard the international Space Station, and we are developing six major laboratory facilities that will support the Space Station research on orbit.

Space Station utilization is a fundamental collaborative process that extends across an array of disciplines, ranging from fundamental science to applied engineering research and technology development.

All of the NASA science organizations and our Office of Space Access and Technology will utilize the Space Station. We in the Life and Microgravity Sciences are simply the biggest user.

NASA continues to seek out the advice of distinguished scientists through our advisory committees and in the National Academy in this process.

We are expanding the access to NASA's unique research facilities for the broader scientific and engineering community.

For example, we have developed a very strong and productive relationship with the National Institutes of Health, and have executed over 18 cooperative agreements in the past year that will enlarge the availability of the Space Station for this community.

In addition, we have similar cooperative agreements with commercial drug companies and others that are interested in utilizing this facility for protein crystallization for other commercial purposes.

By maintaining open communications with the commercial and the scientific communities, and executing cooperative agreements with other agencies and institutions, we are assuring that Space Station utilization is fully integrated into the broad national research and development effort.

This broad national research development program represents an absolutely vital investment in our future economic and national security.

Examples of the orbital research to be done include protein crystal research, which will provide invaluable data for the development of new drugs; the investigation of changes in the brain and the nervous system, on how the nervous system develops and grows, and techniques for changing that growth so that illnesses may be treated—illnesses like Multiple Sclerosis and Alzheimer's—disease, so we can understand and correct them; ground-breaking research into the role of hormones, the secretions inside of our bodies, as they control various parts of our bodies, including the overall mineralization of our bones.

The overall problem of soft bones in the elderly afflicts over 20 million women in this country and a sizable number of men as well. Understanding those processes, and studying them in the microgravity environment will give us key information about these processes.

In addition, we have innovative investigations looking at how solids are formed. These processes are critical to the development of new metals, semi-conductors, and other critical materials.

Our fundamental research on combustion is not only giving us new insights on how to control fire and improve combustion here on Earth, but also how to use combustion in space to produce new materials that can make critical contributions to our future technology.

The technology we are developing for the orbital research in itself often leads directly to technical innovations for industry here

on Earth, and we are committed to continuing the transfer of this kinds of research to the private sector.

For example, surgeons at the University of San Francisco are using our sensor systems within their unborn patients, because they are operating on fetuses with deformities.

They are using our ways of instrumenting them, so they can develop ways, for providing care, post-op care, in utero, to their patients in the future.

These are critical advances in medical technology.

Additional fields of international development, of utilization of the international Space Station for technology and development include communications, robotics, life support, how we store power, and how we generate power.

Advances in all of these areas, plus understanding the basic physiology of humans as they operate in microgravity in space are critical in keeping the door open for future exploration of Mars and the near-earth asteroids by humans in the next century.

They are also critical, I might add, to a number of fields in the commercial utilization of space that were cited in the panel before we spoke.

I am pleased to report that a new era of Space Station research has already begun. Even as we speak, Norm Thagard and two Russian cosmonauts are orbiting the Earth and conducting scientific investigations aboard the Mir Space Station.

With regard to the life sciences portion of that research, I think we can say that with their prolonged observations and the opportunity to make prolonged stays on orbit, we can do some world-class research.

I would also agree that until we have better characterized the microgravity environment, we will not know how much research can be conducted in this setting.

Important investigations are prepared for an extensive program of research that will be invaluable in mitigating the scientific and technical risk when we actually build the Space Station, and in understanding operations for supporting that science.

We have already conducted initial phases of the investigation in Phase One of our Space Station.

Research aboard the international Space Station will begin in 1999. As the Space Station is assembled and more resources and facilities become available, research activities will gradually expand.

At "assembly complete" in 2002, the international Space Station will be the first truly permanent research and technology facility on orbit.

It will give the United States the opportunity to strengthen its leadership in the commercial sector, in science, and in engineering, and to inspire our children to seek educational skills, and to participate in exploration and development of space, and create jobs for tomorrow.

Space Station utilization is an investment in science, technology, and engineering for the twenty-first century, which will drive the economies of the future.

Senator BURNS. Thank you, Dr. Holloway.

[The prepared statement of Dr. Holloway follows:]

PREPARED STATEMENT OF HARRY C. HOLLOWAY, M.D.

Mr. Chairman and Members of the Subcommittee:

I am pleased to have this opportunity to appear before the Subcommittee and report on NASA's plans for conducting the U.S. program of science, technology, engineering, and commercial research aboard the international Space Station. My office, the Office of Life and Microgravity Sciences and Applications, is responsible for selecting and supporting experimental research in the life and physical sciences that is currently conducted aboard the Space Shuttle and the Russian Mir Space Station. We will also select, support, and manage experimental research conducted aboard the international Space Station, and we are developing the six moor laboratory facilities that will support Space Station research.

I am particularly pleased to be here with Dr. Littles. As the launch date for the first element approaches and we focus on our plans to use the Station, our two offices have developed a close, collaborative working relationship. As you may know, Dr. Littles and I jointly lead NASA's Human Exploration and Development of Space (HEDS) Strategic Enterprise. The goals of HEDS indude both using space for experimental research in the natural sciences and developing and exploring space.

Interdisciplinairy Facility

The Space Station will be the world's most diverse interdisciplinary facility for conducting science, technology and engineering research. This unique interdisciplinary character of the Space Station program is reflected in the diversity of scientific, technology, and engineering disciplines represented in plans for using the Station. It is further reflected by the fact that NASA will dedicate 40 percent of its Space Station resources to a program of commercial and technology research through its Office of Space Access and Technology. The Station's role as a platform for creating the knowledge and experience we need to explore and develop space; its role as a new platform for Earth Science; and the opportunities it presents for studying the sun; space radiation, and cosmic dust add to this multidisciplinary character. In short, "Space Station Utilization" is fundamentally a collaborative process that extends across an array of disciplines ranging from fundamental science to applied engineering research and technology development. NASA is working together with the broader international user community to reap the maximum benefits from our investment in this remarkable platform for interdisciplinary research.

NASA-NIH

We continue to expand access to NASA's unique research facilities to the broader scientific community. One of our most successfull efforts at inclusive science community participation has been our increasing cooperation with the National Institutes of Health. Over the past two years, NASA has completed over 18 Memoranda of Understanding with NIH. Five Institutes are participating in planning for the upcoming Space Shuttle Neurolab mission, STS-89, dedicated to research on the brain, and NASA and NIH are jointly sponsoring a number of small payload flights on the Space Shuttle. We look forward to an expanded and productive partnership for Space Station research as well.

Current Orbital Research

Short-duration research aboard the Space Shuttle has demonstrated the value of research on orbit and helped to create a community of distinguished scientists who look forward to a quantum leap in research performance and science return once the Space Station becomes operational. Experimental research on orbit already includes an extremely broad range of scientific disciplines and multidisciplinary cooperation. Each discipline takes advantage of the unique low-gravity environment of space to investigate natural phenomena that cannot be fully investigated on Earth. Examples include protein crystal research which has produced valuable data for developing new drugs; investigations of the nervous system which have produced unique new data on how nerves grow and adapt to change; ground-breaking research into the role of hormones and exercise in controlling bone demineralization (osteoporosis) and muscle atrophy, innovative new investigations into the solidification processes of metals and semiconductors, fundamental research on the process of combustion, and much more.

Overview of Science Research aboard the Space Station

The international Space Station will provide the research community with unprecedented opportunities to conduct new scientific investigations that would be impossible to conduct on Earth. This research will produce valuable findings for application to processes here on Earth while at the same time laying the foundation for the development of space in the future. The following briefly summarizes some of the promising fields of scientific research that scientists will pursue aboard the Space Station.

Space Physiology

Space research provides unique insights into: how the heart and lungs function; the growth and maintenance of muscle and bone; perception, cognition, and balance (neuroscience); and the integration and regulation of the body's many systems (regulatory physiology). Knowledge gaIned from Space Station research will advance our capacity to manage health problems on Earth and is essential to prepare us to travel to other planets.

Gravitational Biology

Scientists study how gravity and force influence the development, growth, and internal processes of plants and animals. Their results expand fundamental knowledge that will benefit medical, agricultural, and other industries.

Biotechnclogy

Orbital research enhances our ability to accurately describe proteins, enzymes, and viruses at the molecular level. This information will enable scientists on Earth to develop new drugs and vaccines much more effectively through the process of structure-based drug design.

Space Station researchers will study methods for growIng human tissues outside the body (tissue culturing). Future research may lead to an improved understanding of normal and abnormal (cancerous) tissue development, with important implications for the development of new drug therapies and applications for transplant research.

By growIng protein crystals and researching cell cultures in space, our biotechnologists in science and industry can advance knowledge and develop new commercial products that can treat a variety of diseases. Researchers are already using results from shuttle flights to develop new drugs to treat diabetes, emphysema, and other medical problems.

Fluid Physics

Researchers use low gravity to study the properties and behavior of fluids (liquids, gases, and mixtures). Fundamental knowledge of fluid behavior is essential to industrial activities ranging from energy production to materials engineering.

Materials Science

Researchers use low gravity to advance our understanding of the relationships between the structure, processmg, and properties of materials. Findings in materials science have very broad applicability to industrial processes, including the production of semiconductors, glasses, metals, alloys, polymers, and ceramics.

Combustion Science

Scientists use microgravity to simplify the study of complex combustion (burning) processes. Since combustion is so widespread in industry and our daily lives, even small improvements in efficiency may have very large benefits for the economy and the environment.

Microgravity Physics

Scientists use microgravity to test fimdamental theories of physics with degrees of accuracy far exceeding the capacity of Earth-bound science. Physics in microgravity sheds light on phase transition phenomena such as high-temperature superconductivity.

Advanced Life Support and Human Factors Research

Researchers work to improve the efficiency and reliability of life support systems and to enhance and productivity of future crewed space missions. Continued developments in this field are essential to our quest to explore and develop space. Life support technology is already finding broad application in medical and environmental fields and may support future developments in the commercial aircraft sector.

Space Station Benefits

In addition to direct contributions to our understanding of the natural world, expanded knowledge in these fields is a prerequisite for extended missions of exploration and the long-term development of space resources. Space Station research is an investment in the science, technology and engineering of the twenty-first century

which will drive the economies of the future; it is also an investment in a new frontier for exploration and development.

Technology that we develop for orbital research often leads directly to technical innovations for industry here on Earth, and we are committed to encouraging this kind of transfer to the private sector. For example, surgeons have recently begun using NASA sensors to monitor the health of the unborn following prenatal surgery to correct birth defects. Technologies for remote diagnosis developed for astronauts may soon provide extended access to health care for under-served populations. Additional fields of technology research aboard the Space Station will include communications; robotics and remote operations; life support; and power generation and storage. NASA has been a source of innovative technologies for American industry for decades, and research on orbit will continue to provide a steady stream of these valuable technology transfer opportunities.

It is important to understand the contributions of orbital research not as a series of stand-alone projects designed to solve one mystery or another, but as part of the overall American scientific and technical enterprise that is responsible for so much of our prosperity. Space Station scientists may not discover a cure for cancer or AIDS by their singular efforts, but they will make significant contributions to the overall advancement of bio-medical sciences and biotechnology that may one day contribute to the discovery of such cures. Similarly, Space Station research will not necessarily lead directly to the development of new superconductors, but orbital research is already making a significant contribution to our understanding of phase transition phenomena such as high temperature superconductivity. The U.S. investment in this research is an investment in the future. It will add to our scientific expertise, support the development of the technologies of the 21st century, and create jobs and economic growth for our children and our children's children.

NASA is committed to using the unique attributes of human spaceffight to inspire excellence in math and science among America's youth and raise scientific literacy at all levels. At a time when economic competitiveness depends upon educational excellence, NASA will use Space Station research to support the broader national effort to enhance scientific literacy and excellence in science education.

NASA is managing America's program of Space Station research to produce a stream of scientific and technological benefits while, at the same time, taking advantage of the unique attributes of research in space to inspire and encourage excellence in science education on Earth. We will use the Space Station to expand our understanding of the natural world while laying the foundations for an expanded human presence in space in the future.

Selecting Science

The United States program for orbital research has set the international standard for selecting investigations for ffight. We have established a regular schedule of open research solicitations and a rigorous peer-review process for allocating resources to the highest quality scientific investigations in the world. NASA has already begun to expand our community of orbital researchers, and we anticipate that our current group of 654 principal investigators will rise to over 900 by the turn of the century in order to take advantage of Space Station research opportunities. We received over 1,400 new research proposals in 1993–94. Because resources are tightly constrained, we typically select only the top 20 percent of proposals for funding and even fewer for ffight. As noted above, the demand for access to Space Station resources extends beyond our life and microgravity researchers to include commercial, technology, engineering, Earth Science, and Space Science research.

At every step of this program we seek out the advice of distinguished scientists through our own advisory committees as well as through the committees of the National Research Council.

Developing Laboratory Facilities

Development of the six major laboratory facilities for Space Station research is progressing on schedule for launch readiness by 1999 for five of the six facilities; the centrriuge will be ready for launch in 2001, which is three years ahead of its earlier schedule and at reduced cost. The Space Station facilities have been designed in consultation with the scientific community to support groundbreaking research in disciplines including neuroscience, muscle and bone research, research on the heart and blood vessels, combustion science research, materials science research, biotechnology research, fluid physics research, and more. Researchers from around the world are looking forward to the chance to use the unique research environment

of space to probe the fundamental scientific questions in these and other fields of research.

Opening the Space Station Era

I am very pleased to report to this committee that the Space Station era of orbital research has already begun. Even as we speak, Norm Thagard and two Russian cosmonauts are orbiting the Earth and conducting scientific investigations aboard the Mir Space Station. With the launch of Thagard to Mir, U.S. and international orbital research began a new era of expanded opportunities for experimental research and technology development on orbit. Next month, the first docking mission between a Space Shuttle and a Space Station will take place. A total of ten people will be together on orbit in docked spacecraft for the first time, and, when Thagard and his two Russian colleagues return to Earth aboard the Space Shuttle, they will be the first human to ride to orbit in one vehicle and return in another.

While the Mir Space Station does not provide the same quality of laboratory facilities and resources as those which will be provided by the international Space Station, we are very excited by this opportunity to expand our experience with long-term orbital research operations. The Russian Space Agency will launch over 4,000 pounds of U.S. research equipment to Mir aboard two Russian modules (Spektr and Iririroda) in the coming months and we will conduct over 100 peer-reviewed research investigations. Several U.S. industry-sponsored projects will be flown on Mir as well. These commercial technology development projects, conducted through NASA's Centers for the Commercial Development of Space and NASA field centers, Include a biotechnology experiment involving plant cell culturing and a materials science experiment that will use Russian hardware. This cooperative program with the Russians is called Phase 1 of the international Space Station with good reason—it is preparing us to take full advantage of the International Space Station from the first day that resource becomes available for research. We will be reducing the engineering risk in development of scientific equipment for use on Space Station and will obtain invaluable experience working with our Russian colleagues in providing the logistical support for orbital science aboard an operational Space Station.

Research aboard the International Space Station will begin in 1999, followIng the delivery of the U.S. Lab and supportIng laboratory equipment. Early research aboard the Space Station will focus on Investigations that require relatively few resources and can be conducted In simple facilities. As the Space Station is assembled and more resources and facilities become available, research activity will be expanded accordingly. At "assembly complete" in 2002, the Space Station will be humanity's first true permanent research and technology facility on orbit offering an array of six moor modular laboratory facilities and a permanently present human crew. NASA and the U.S. scientific and engineering community are providing the leadership that will make this possible. This leadership will be joined with critical contributions from our International partners to maximize the scientific return from this magnificent research facility. This will allow the United States the opportunity to strengthen leadership of its commercial sector in science and engineering. It will Inspire our children to seek the educational skills to participate In the exploration of space and create the jobs of tomorrow.

Senator BURNS. Did I hear that you have some concerns about some questions that were brought up with the previous panel about whether we are moving too fast into privatization or commercialization?

Dr. HOLLOWAY. No, sir. Quite the contrary.

Senator BURNS. That is what I thought, too. I thought I misheard you.

Dr. HOLLOWAY. We are moving, I think, at a very appropriate rate. I am very supportive of that particular kind of development.

Senator BURNS. Dr. Littles, in your estimation, and you heard the testimony to the previous panel, I just have a couple of questions. The current plan—are we relying too much on the Russian participation?

Dr. LITTLES. We do not believe that in this point in time we are. Of course, when we incorporated the Russian capabilities into this design, as we have already discussed here this morning, we made

significant improvements to the capability of the Space Station to conduct the science in the future.

In incorporating the FGB, and the service module, and the Progress vehicles, we are also taking advantage of an existing capability that has been developed over a lot of years by the Russians.

So we are taking advantage of a lot of capability that is there. We are using it to save money and to save time.

Now, obviously, there is concern. There are potential things that could happen to cause us to take a different route. And we are doing contingency planning to take into account a wide spectrum of potential outcomes if something should happen.

Of course, the first scenario would be if we still could use the Russian industry as contractors, we could still use that hardware if the government just dropped out.

Senator BURNS. What is the most troubling aspect of their participation, as far as you are concerned?

Dr. LITTLES. Well, I do not have a single thing that is troubling in terms of the technology we are using, the program we have put in place. I would assume a political uncertainty would be the thing that would be of most concern to the country, as a matter of fact.

Senator BURNS. Dr. Holloway, we heard the testimony of about this Space Station's facilities and instruments, will they be ready for use when the station is ready to accommodate them? Are we on-line with that, with all the equipment?

Dr. HOLLOWAY. Yes, sir. We are on-line with all of those. All the facilities, the protein crystal growth facility, the facility for the furnace, the facilities for human research as well as the biology facility will all be delivered in 1999, and ready for going on orbit.

In fact, one thing that I think we have to communicate about, because we have actually changed the schedule, is that actually the centrifuge will be delivered in 2001, not in——

Senator BURNS. I was going to ask you——

Dr. HOLLOWAY [continuing]. Not in 2004. We will deliver a four-arm centrifuge in 2001, for launch, and in 2004, we will finish that by putting up a six-arm centrifuge, which will make it a more ready facility at that time. But that is time of completion, not time of delivery.

Senator BURNS. In other words, you are telling us that there will be research done with the centrifuge prior to 2004.

Dr. HOLLOWAY. Yes, sir. As soon as we have completed the Space Station, the centrifuge will be ready to start work.

Senator BURNS. The changes in the NASA organization, resulting from Zero-Base Review, how do they affect the Office of Life and Microgravity Sciences and Applications?

Dr. HOLLOWAY. Well, of course, any time you reorganize an entire agency, everyone is affected. We are affected in that general sense.

It has given us an opportunity to look at more efficient and more effective ways to look at our science, and how we support our science, and we are taking the opportunity, in the context of the zero-based review, for establishing some ways of managing science, in collaboration with universities and industrial cooperatives that

may prove to be very helpful at some of our centers in managing the science.

We are looking at the establishment of potential institutes at several of the places that we do our science, and that is currently being very actively looked at, at JSC, at Ames, and some of our other science centers.

By the way, that is not just in Life and Microgravity Sciences, that stretches across the board to all of the science offices, who are looking at exactly that same approach.

This seems to be a way that we can open ourselves to more collaboration with the outside, while preserving that critical role of the NASA scientist, of making the bridge between the great technical and engineering capability of science, and the science community, which is so critical to accomplishing our mission.

Senator BURNS. Now, I have sort of a different kind of a question here. As you know, we can sit here and we can talk about the science, and we can talk about all the people that are involved in this thing, and I was going to ask Dr.

McPherson this, and I hope I get the chance to visit with him before this is all over.

We can sit here, and we can talk about all of the advantages and everything that is to be gained from this exercise, but there is a political side of this thing, as to how do we relay that story in lay terms to the American people, so they can understand it, because I would be less than honest with you if I did not say that there are going to be some people in these tough budget times that are doing a lot of prioritizing, of where we spend our money. This will be a subject of discussion.

So how would you—you put in my place, where I have to go home to Montana, and tell them all the wonderful things that we are doing with space, with NASA, how do I explain that in lay terms to people who do not have the access to information, or are not interested in this as maybe I would be?

Dr. HOLLOWAY. Well, perhaps you could use the following sequence of argument. You live out in the big country. There are lots of isolated areas, I believe, in Montana.

Senator BURNS. Well, I always say there is quite a lot of dirt between light bulbs out there.

Dr. HOLLOWAY. Right. And I come from Oklahoma, where most of that is filled with dust instead of dirt. But the point being that telemedicine, which we developed and utilized to remotely deliver medical care, and are developing the technology associated with that, has very real implications for folks who live in those areas, and who work there, and who may be in a remote area and have seen the doctors disappear from the small towns. The utilization of electronic media to both carry out diagnosis, and even more, to actually achieve treatment at a remote site, is one part of that.

In addition to that, you might talk about the overall effect for the elderly in your area. For instance, there are two major problems that face us when we go into space. One has to do with balance, another has to do with the fact that the bones become softer; that is, we lose calcium in them.

That is a change that goes along with aging, aging for all of us. It is particularly an affliction that besets women. As I noted before,

there are 20 million women in this country with osteoporosis; in fact, more than that at the present time.

By studying and evaluating our young astronauts, we can actually do experiments both with our astronauts and with our collaborators, the animals that travel in space, to understand this process in the bone, and the utilization of exercise, drugs, and hormones, so that we can prevent this kind of problem.

What is the overall consequence of that? Well, in fact, balance is one thing that is lost, while we are getting these bones that are softer and the muscles that are weaker.

What happens when people get old is that they step off of a curb, fracture their hips, and then fall. That is a deadly event, as well as a tremendously expensive event in your state and all other states with regard to medical care.

It is the prevention and understanding of exactly that process that is at the heart of much of our balance and bone research in space. Beyond that, fundamental understandings of how gravity affects the growth of plants has real implications for agronomy, for what kind of plants you plant out in your north forty to produce more productive plants.

Furthermore, we study the turnover of waste in our life support systems and better ways of doing waste management for the Space Station, so that we can do a better job taking care of waste here on Earth in a more effective and efficient manner.

Aside from that, there are direct effects in terms of jobs. A one or 2 percent change, say, a 2-percent change in understanding the efficiency of combustion will provide more than $7 billion a year in terms of payback to the United States.

And that is one of the areas where convection makes it very difficult to study aspects of combustion here on Earth, and operating in a microgravity environment helps out.

And finally there is a whole sequence of drugs, and here you really ought to talk to Dr. McPherson, because he is truly one of the leaders in this area, in which the creation of protein crystals is in use to create drugs, vaccines, and whole new systems for preventing disease.

Actually, the Space Station is an institute that has its effect in answering not just one scientific question, which sometimes people think of as "big science," but rather, in carrying out multiple kinds of science with contributions that go to health, that go to work, that go to industry, that go to the creation of new technologies, that go to almost every aspect of living for people in this country.

Senator BURNS. Thank you very much. Senator Kay Bailey Hutchison. Thank you for joining us this morning.

STATEMENT OF SENATOR HUTCHISON

Senator HUTCHISON. Thank you, Mr. Chairman.

I do have a statement that I would like to enter for the record, and which I will not expect you to listen to in its entirety. But I appreciate this opportunity again.

[The prepared statement of Senator Hutchison follows:]

PREPARED STATEMENT OF SENATOR HUTCHISON

During my time in the Senate, I have been a vocal supporter of the Space Station program. I believe that sometime within the next 50 years, the first human from Earth will walk on the planet Mars. She will be stronger and healthier than her mother and grandmother, in part because our generation made the decision to take the next step in space exploration: We decided to build the Space Station.

The Space Station continues to be an excellent example of what the federal government can do and should do to invest in the future of people, the economy and the well-being of our international relationships.

President Kennedy said that "the exploration of space will go ahead, whether we join in it or not, and it is one of the great adventures of all time, and no nation which expects to be the leader of other nations can expect to stay behind in this race for space."

Although the race for space has been replaced by a steady march of exploration, the quest for technological leadership continues to be a mortal international competition.

What is technological leadership in this day and age? What does it mean to someone struggling to make ends meet or worried about sending their children to college? It means America will continue to grow, and opportunities will continue to expand. It means that new discoveries will turn into new products, and the industries that develop to make those new products will mean new jobs.

Experience clearly shows us that investment in NASA space exploration yields long-term productivity advances from new technologies developed from space and aeronautics programs. The space program has generated over 30,000 spin-offs, including commercially valuable products like satellites and major advances in computers and television, high quality software, high performance computing, fiber optic networks, water purification systems, teflon, digital watches, and cordless tools.

The research and development associated with the Space Station will promote U.S. competitiveness in such areas as advanced metals, electronics, robotics and automation, scientific instrumentation, and precision bearings—areas that U.S. competitiveness is weak and losing ground in the world market.

Most notably, in my opinion, is space exploration's contribution to medical science. NASA technology medical spinoffs include advanced pacemakers based on technology developed to enhance satellite communications with earth stations, advanced body imaging/CATscan/MRI technology evolved from NASA earth sensing technologies; advanced wheelchair technology and automobile adaptation for the disabled derived from lunar rover technology.

The Space Station will provide a research facility to conduct materials and life sciences research in a microgravity environment. To date, limited microgravity research conducted on the space shuttle has provided scientists with important clues to the causes of osteoporosis, diabetes and other debilitating diseases. However, space scientists world-wide must compete and wait for the relatively few opportunities available to put their experiments on-orbit.

A permanently manned space laboratory is necessary to provide researchers with more extensive research facilities in a controlled microgravity environment. Extended human space flight will allow scientists to modify their experiments on orbit and take advantage of unanticipated results, which have has historically led to great scientific breakthroughs—perhaps to a cure for cancer, AIDs, osteoporosis and other debilitating and costly diseases.

Investment in NASA research and technology development yields a 9 to 1 return on investment over time; in other words, spinoffs add up to $9 dollars to the U.S. economy for every $1 invested in NASA research. There are those who say that the costs of making this investment in the future is too high. We can't afford not to make this investment.

I am proud of the work being done at the Johnson Space Center to develop the Space Station and make it a reality and am pleased that it will continue, as announced by Administrator Goldin last week.

I was alarmed by proposals to diminish the JSC role in engineering necessary to design, develop and test spacecraft capable of taking humans into space and returning them safety to the earth. The concept of transferring management or operations of these engineering activities away from the JSC—the human spaceflight center—could not have resulted in any efficiencies.

In fact, NASA made JSC the lead Center for the Space Station in order to avoid duplication and to implement integrated product team management techniques (called "Integrated Program Teams "). These geographic and organizational synergies with engineering, crew and flight operations (which are critical to mission

success and safety) would have been lost as a result of shifting spacecraft engineering and moving shuttle activities away from the Space Station program.

With essential human spacecraft engineering functions at JSC, I am confident that the Space Station program will remain on time and within budget and able to respond to the complexities—both management and operational—that are inherent to human exploration of space.

Senator HUTCHISON. After our meeting last week, a lot has intervened, and I would like to clarify a couple of things that have happened in the last week with you, Dr. Littles.

The press release, and what we saw when we met with Dan Goldin last week, indicates that we will be moving to the single prime contractor on the space shuttle program, and that would be perhaps the prelude to privatization.

And yet, I also would like to talk about the link between the space shuttle and the Space Station, and the importance of the co-location, the continued co-location of those two functions, because of the need for integration and the need for the people who are engineering it to be with the people who are using it.

I think that point has been strengthened with the people with whom I have talked lately.

Would you comment on that, and if you do think that the co-location is going to continue to be strengthened in the future?

Dr. LITTLES. Well, yes, Senator. As I mentioned to you last week, I do not envision any change relative to the functions that are being conducted at JSC. We will continue to have that engineering support that is required for our operations to be done at JSC.

Now, as I mentioned to you last week, as we move to a more consolidated work force under a contractor, more of that work would be done by the contractor work force, and the government work force will back off, as Dr. Kraft recommended.

But those functions that are necessary for support of operations, and there is engineering support there required, understanding of the subsystems, will continue to be there.

Relative to Station and Shuttle as well, what I envision, as we move downstream, is a consolidation of the operations between Shuttle and Station, and moving those into one organization.

Senator HUTCHISON. So you do think the co-location issue should be one of strength, that it should be strengthened as we go into the operations phase.

Dr. LITTLES. Well, I see it staying fundamentally as it is, with those necessary engineering support capabilities still residing there where that work is done.

Senator HUTCHISON. Do you foresee, when we go to one single prime contractor, that contractor being located in one place, and, if so, would it naturally be JSC to work best?

Dr. LITTLES. No. I do not see all that work being done in one place, because, obviously, there is a significant fraction of the total operations work that is done at KSC.

So there will be contractors there to do that work, and there will continue to be the support required for mission operations and other functions at JSC.

Whether we will have that all lumped into one contractor organization, or whether there might be two pieces of that, is dependent upon a study that is going on right now by John O'Neill, at JSC,

looking at consolidation of mission operations across the total agency.

And depending on the outcome of that result, the structure from the contractor's side and the government's side could change a little bit.

But fundamentally, I see, the contractor work force required to do the work at the locations still being there to do it.

Senator HUTCHISON. Still being—excuse me?

Dr. LITTLES. At the location where the work is required, both at KSC and at JSC.

Senator HUTCHISON. So you are looking at possibly two functions, when we go to the prime contractor, one being operations at KSC, and the engineering design function continuing at JSC, is that sort of the——

Dr. LITTLES. Actually, the way I look at it, there are three fundamental functions. There is the design effort, which will remain under government management. Even after we transition to a more focused consolidated contractor effort, we plan to maintain that design activity on the government side, as it is now.

So that work that is—the design work will be done, and the orbiter will still be done by and managed by the Civil Service work force at JSC. The work that is done on the elements at Marshall will still continue to be done there.

The other two aspects, and there are actually two types of operations done at KSC. The ground operation is fundamentally the work on the hardware to do the processing, and get ready, and the launch at the Cape, and then the flight planning and mission operations are done at JSC.

Those are the two elements that we are going to pull together as much as possible and consolidate that under a single entity, or depending on the result of John O'Neill's study, there may be a piece of that that might be consolidated across the agency. And that is still the question we have.

Senator HUTCHISON. OK. Tell me again, which two functions do you see as consolidating, the mission control, plus what other?

Dr. LITTLES. We will consolidate, to the maximum extent possible, all the operations functions, which includes the flight mission operations at JSC and the planning for that, and that part of the work that is done at KSC.

But exactly how that will be structured, we will not know until—well, as a matter of fact, I have told Dan Goldin that I will come to him on or before the fifteenth to give him that information.

Senator HUTCHISON. The fifteenth of June?

Dr. LITTLES. The fifteenth of June. Yes.

Senator HUTCHISON. And that is the John O'Neill study.

Dr. LITTLES. Yes.

Senator HUTCHISON. And that will be the preliminary to going out for the prime contractor, to give the prime contractor the parameters of where you would see the functions being.

Dr. LITTLES. Yes. That will be—when we reach that point, we will understand how we expect the organization to be implemented and structured on the contractor's side, as well as how we plan to have that done on the government side.

And we will begin then to put in place a more detailed understanding of that transition, because, again, as I mentioned last week, there are a significant number of contracts involved, and all those have to be pulled together and integrated.

So we will be putting into place a plan to do that, a transition plan. It will take us some period of time to put that in place, and then a longer period of time to actually do it, because we are going to transition from an organization where we are fundamentally on the government side, integrating all those contracts, to a concept where we are basically letting the contractor do that. And we have to do that very carefully.

Senator HUTCHISON. Mr. Chairman, my time is up. I had one more question, but that was about it. Do you want to take another round, and I will wait?

Senator BURNS. No. I am only going to ask him one more question. That is all I have.

Senator HUTCHISON. OK.

Senator BURNS. Then I have to get from space to the bare necessities of grazing.

Senator HUTCHISON. Well, I will be happy to take space, if you want to go to grazing.

Senator BURNS. I will tell you what, may I just ask this question, and——

Senator HUTCHISON. Sure.

Senator BURNS [continuing]. And you can close it up?

A while ago there was some concern by CRS about Boeing not having signed the contracts yet for the subcontractors.

Does that concern you?

Dr. LITTLES. Well, we would much prefer that that activity were already behind us. It is ongoing very actively. We have, in conjunction with Boeing just this week, put some additional activity in place, to try to move that forward a little faster.

So yes, we would like to have it done, but it is not a major concern to us at this point in time. We would like to conclude it just as soon as possible, because until we do that, there would still be some uncertainty relative to the dollars associated with those activities.

Senator BURNS. Well, the reason I say that is because we have to pull a lot of elements together to make this—not only the Russian participation, but also our Canadian,

European, and Japanese friends, and then to one contractor, of which Senator Hutchison has been concerned.

Pulling all those things together is no easy task, and I am just wondering about your feelings on that, and anything else the other panel had to deal with. Would you like to answer some of those situations?

Dr. LITTLES. I think Randy Brinkley would like to comment on that.

Senator HUTCHISON. Mr. Chairman, could I just interrupt? I just looked at my schedule. I am presiding at 11:00——

Senator BURNS. OK.

Senator HUTCHISON [continuing]. So I will have to go.

Senator BURNS. You better go.

Senator HUTCHISON. Thank you. Thank you very much. I feel a lot better this week than I did last week, Dr. Littles. Thank you.

Mr. BRINKLEY. Senator Burns, in a comment to that, the $5.63 billion contract that we have with Boeing as the prime, although we have not completed the product group definitization, or Boeing has not, we have still continued to track the cross in that funding profile of the product group participation, and they are staying under cost and on schedule with the contract that we signed with the prime.

So although we want to complete that as quickly as possible, we are staying under cost and on schedule with our prime contract that we negotiated in February.

Senator BURNS. Is there any other subject that was brought up during the first panel on which you would like to comment, just off-hand?

Mr. BRINKLEY. I would like to comment on the concerns about EVA. The EVA has increased, from a year ago, about 200 hours; 150 of those 200 hours were related to changing and the configuration to get the Russians off the critical path, and to bring in early power.

Those decisions, all 200 hours, we have looked at and done an analysis. We have maintained adequate margin on each and every flight.

We are confident in our ability to be able to successfully execute the EVA requirements that we have on the program.

In fact, we have the same team on the program now that was successful with the Hubble space telescope, which was much more demanding than anything that we have in the assembly sequence today.

We do not take EVA requirements in a cavalier fashion at all, but we believe that if we approach it in a very well thought-out, methodical way, if we prepare correctly, if we ensure that we have adequate margin on each and every EVA, that those things will take care of themselves, just as they did on the Hubble mission. And that is our approach in dealing with them.

Senator BURNS. Are there any other comments?

Dr. Holloway?

Dr. HOLLOWAY. I have just a brief comment on that last matter, because another question was raised about the extent to which we are able to use the Russian experience in the context of the EVA. We are, in fact, working very closely together with the medical folks in Russia, who have supported the EVAs over the years, as well as those who have designed and worked this.

We now have a very active sharing, so that we understand much of their experience, and, of course, even as we speak, yesterday, at least, another EVA was finished on Mir, with Norm Thagard on board.

So we are getting very active information about experience from numerous sources, to try to understand all the aspects of this problem.

Senator BURNS. Dr. Littles?

Dr. LITTLES. I have one more comment on EVA. One of the things that I have been impressed with, as I have come to under-

stand how the Russians deal with Mir relative to EVAs, they do a lot of reconfiguration of that vehicle.

They do a lot of challenging EVAs, and they are doing a series of those right now to get ready for STS–71 to dock.

That is one of the areas, as a matter of fact, that, in phase one, we are taking advantage of, is understanding how they do that work, and learning from it. I think that is going to be a very valuable experience for us.

Senator BURNS. Well, I want to thank you for coming this morning, and for your testimony.

There again, I am told by other committee members, there will be questions submitted, and if you could respond to the committee and to the individual senator, we would appreciate that very much.

Senator BURNS. We appreciate your testimony here this morning, and your enthusiasm for this project. So thank you very much.

This subcommittee is adjourned.

[Whereupon, at 11:04 a.m., the hearing was adjourned.]

APPENDIX

PREPARED STATEMENT OF THOMAS A. SCHATZ, PRESIDENT, CITIZENS AGAINST GOVERNMENT WASTE

Before the Senate Commerce, Science and Transportation Committee

Good afternoon, Mr. Chairman. Thank you for the opportunity to testify before the Commerce, Science and Transportation Committee. My name is Tom Schatz and I represent 600,000 members of Citizens Against Government Waste (CAGW). Your interest in CAGW's comments are a true indication of the tidal wave of change that swept the country on November 8th.

CAGW was created 11 years ago after Peter Grace presented to President Ronald Reagan 2,478 findings and recommendations of the Grace Commission, formally known as the President's Private Sector Survey on Cost Control. These recommendations provided the blueprint for a more efficient, effective, less wasteful, and smaller government.

Since 1986, the implementation of Grace Commission recommendations has helped save taxpayers more than $250 billion. Other CAGW cost-cutting proposals enacted in 1993 and 1994 will save more than $100 billion over the next five years. CAGW has been working tirelessly to carry out the Grace Commission's mission to eliminate government waste.

Mr. Chairman, you and the members of this committee face one of the most important tasks confronting our country—eliminating unnecessary spending and streamlining the government. Not only do you have an opportunity to save tax dollars, but you also have the chance to end the wasteful spending habits of the past.

The first step is to reverse the old assumptions. Congress has often viewed programs as permanent fixtures on the fiscal landscape. Rarely are programs evaluated and scrutinized. The truth be known, the fiscal landscape is really a wasteland of ineffective and costly programs that are funded without question.

The Space Station is the perfect case in point. Despite the station's problems, Congress and the administration are not prepared to shelve the program until less costly alternatives are found. Some may argue that eliminating the Space Station would be a tragedy, but in its present state, funding for the station should be eliminated until the program can be fiscally brought into line fiscally.

Since 1984, when the Space Station was first proposed by President Reagan, the program has suffered from huge cost overruns and lacked a clearly defined mission and purpose. There is nothing to suggest to taxpayers that these costs will stabilize soon because there is still no clearly defined mission. At first, the Space Station was meant to assist in the exploration of the solar system. Later, it was justified on the grounds that it could advance our knowledge in the fields of microgravity and life science. Now the Space Station is supposed to promote international cooperation. These purposes on the surface appear to be worthwhile, but the continuing revision of goals suggests that there is no overriding goal for the program which secures the interests of taxpayers in an efficient and economic government.

According to NASA, the Space Station will cost nearly $71 billion to build and operate, 788 percent more than the original $8 billion price tag presented to Congress in 1984. Since 1984, taxpayers have spent $11.9 billion on the Space Station and not a single piece of hardware has been put into space.

The $71 billion price tag does not include the salary costs of the thousands of NASA employees who will work on the station over the next two decades. The figure also does not take into consideration several items that could drive up the cost even further. At least $438 million will be required to upgrade the space shuttle so it can reach the Space Station with a full payload. An additional $100 million is needed to offset Canada's withdrawal from the program because the Canadian government can no longer afford the costs. There is also the unknown cost of upgrading the Russian launch facility in Kazakhstan. Nobody is sure who will bear the cost of the renovations or the extent of the costs. The cost of the module to house the centrifuge, which is vital for life sciences research, is also not included in the construction budget.

If the Space Station gets off the ground, the U.S. would have to maintain it for 20 years or more. A 1990 NASA study projected that 3,700 hours of space walks would be required to maintain the station annually. In the first 33 years of the space program, U.S. astronauts logged less than 500 hours of space walks. Clearly, the maintenance program is beyond current capacities.

The budgetary burden of the Space Station is so great that it is killing the space program. A space shuttle mission and scheduled shuttle improvements have been

canceled. NASA cannot afford to begin any new science program without pulling the plug on existing programs. Important analysis of data from other spacecraft, including the Hubble Telescope, is underfunded.

Due to the sheer weight of its budgetary needs, the Space Station drives and dominates the nation's space policy. The result is the loss of a balanced space program and the strangling of technical advances in most fields of space exploration. The interests of the country are ill-served by betting most of the farm on one program.

On a broader scale, the spending caps which will freeze discretionary outlays for the next five years means that funds available to the appropriations committees will get smaller and smaller compared to need. The Space Station which is funded by the Veterans' Administration and Housing and Urban Development appropriations subcommittees in the House and Senate will not be spared from the budget squeeze. The failure to control the costs of the Space Station means that it not only dominates NASA's budget but it also competes for funds that could go to veterans and public housing programs: it puts the squeeze on the entire budget. At a time when Congress is seeking ways to reduce spending and balance the budget, an out-of-control Space Station is an unaffordable and unnecessary burden.

Many scientists believe that the Space Station cannot be justified on the grounds of scientific discovery. Since 1984, it has been redesigned seven times. In each instance, the redesigned station has less scientific capability than its predecessor, while costing more money. As a laboratory in the sky, the Space Station has all the markings of a dud. Some Earth-bound laboratories have a greater capacity for scientific discovery than the confines of the Space Station.

Most of the research planned for the Space Station—especially the life sciences—could be done cheaper elsewhere. In 1993, 10 scientific societies in a joint statement laid that the Space Station is a "multi-billion project of little scientific or technical merit that threatens valuable space-related projects and drains the scientific vitality of participating nations."

Some sections of the scientific community have argued that while we're building an extraordinarily expensive laboratory in space, there are pressing needs here on earth that will be unmet. Given the huge cost of conducting medical research in space, it is clear that research on earth could produce more results and sooner. The exorbitant cost of the Space Station is therefore a threat to basic research that currently is struggling to secure funds to continue the fight against deadly diseases. Because of "big science" projects like the Space Station, many worthwhile basic research projects which could dramatically change the quality of our lives have been underfunded. "Big science," more often than not, promises more than it can deliver. The space station program in its current form can only short-change taxpayers.

Everybody agrees that without solid scientific research, America will stroll into the 21st century while other countries gallop to future prosperity. Ironically, the Space Station could be the burden that slows our gallop to a walk, if not a crawl.

The claim that the Space Station is an important program for fostering better ties with Russian is not persuasive. The Space Station has never been a priority for Russia. The current plan to secure Russian involvement does not advance the U.S. goal of privatization in Russia. Instead, the current plan requires cash transfers to a large Russian state agency, directly contradicting the goals of U.S. policy and assistance toward Russia, which are to support democracy and economic reform.

The Space Station program requires a long term commitment. Nobody can guarantee that U.S.-Russian relations will be stable through the year 2002, or the subsequent 30 years of the Space Station's operations. By making the Space Station part of U.S. foreign policy, the program is exposed to the state of flux that characterizes international relations. During the 1970s, U.S.-Soviet cooperation in space did not transcend the volatility of foreign relations. Cooperation in space lapsed after the invasion of Afghanistan.

Who can say that the next time there is a crisis in U.S.-Russian relations there won't be cries to cancel the Space Station. What happens if the Russians sell missile components outside the Missile Technology Control Regime guidelines? Will the Space Station be considered suitable for sanction? Will the Space Station become a political football to be kicked around whenever the U.S.-Russian relationship hits rough waters?

As the program stands today, the proposed role of Russia is critical for the space nation's completion. But the political horizon in Russia is unpredictable and changing daily, casting shadows on whether Russia is politically stable enough to support the program until its completion. It should also be noted that if Canada was forced to withdraw support from the program due to economic reasons, then Russia's shaky economy also poses concern for even the most ardent supporter of the station. Con-

sequently, the Space Station program in its current state stands at the mercy of forces outside our control. It is time to reevaluate the entire program.

The national debt is more than $4.8 trillion and justifies tough choices such as the postponement of the Space Station. Taxpayers are no longer amused by inadequate and irresponsible management of our government because their future is in jeopardy. The budget crisis cannot be ignored, and that's why their amusement has been replaced with outrage. Members of this committee must be equally as outraged. The Space Station program should be halted until a solution is found for its myriad of problems.

Restoring fiscal sanity to our nation is the most important job for the 104th Congress. The country is awash in a sea of red ink, and every day slips perilously close to bankruptcy. The national debt is expected to rise to nearly $6 trillion by the end of the century. This is not the legacy that we should leave to our children and grandchildren; spending has not been cut to the bone. Money is being wasted daily and the clock is ticking. We must act today for the sake of the future. This concludes my statement for the public record.

QUESTIONS ASKED BY SENATOR BURNS AND ANSWERS THERETO BY DR. HOLLOWAY

QUESTION 1: Will the Space Station Facilities and instruments be ready for use when the station in [sic] ready to accommodate them?

Answer 1: The six major facilities are on schedule for use when the international Space Station is ready to accommodate them. Although the facilities have not yet been assigned to particular flights in the assembly sequence, the FY 96 budget request assures that five facilities plus the EXPRESS Rack will have elements ready for launch by the middle of 1999. Available user payloads are expected to exceed the available user upmass and the Station's capacity to accommodate user payloads early in the program. Enclosed is a graphic illustration of the scheduled development of the six major facilities and the EXPRESS Rack.

All of the initial apparatus for the international Space Station Facility-Class Payloads are currently in either the definition phase (phase A/B) or under full scale development (phase C/D). These Facility-Class Payloads are composed of the common mechanical and electrical equipment, usually called "the core," and the specific experiment apparatus developed for individual investigators or groups of investigators, usually called the "experiment modules." Experiment modules will continue to be developed, based on scientific selections scheduled on regular intervals during the life of the international Space Station. Therefore, a substantial amount of development work will continue into the "operations" era of the Facility-Class Payloads after Station Assembly Complete.

Attached is a schedule for facilities development that reflects NASA's current planning.

QUESTION 2: How are we using our experience gained for conducting research in the Spacelab to conducting [sic] research on the Station.

Answer 2: NASA and the scientific community draw upon Spacelab experience for selecting international Space Station investigations, designing Station facilities, and planning for Station operations.

NASA is drawing upon a diverse community of researchers, engineers and managers from within NASA, from within the scientific community, and from within the international partner agencies, to plan for and execute a program of international Space Station research that maximizes America's return on its investment in the Station. Each of these communities harbors a depth of experience with research not just aboard Spacelab, but also aboard other spacecraft such as the Russian Space Station Mir, the Russian Cosmos free flyer satellites, and Skylab. Because each orbital opportunity is so precious, NASA has always worked to assure that knowledge and experience from earlier flights and from a vigorous program of ground-based research are combined to maximize performance and mitigate risk on successive flights.

The NASA offices currently responsible for conducting scientific research aboard Spacelabs will also be responsible for designing, conducting, and managing similar scientific research aboard the international Space Station. NASA's program scientists and engineers with experience conducting research aboard Space lab will be responsible for the Station research program as well. In addition, NASA's other Station users including Mission to Planet Earth and Space Sciences will apply their experience on the Space Shuttle when designing their instruments and experiments.

The Second International Microgravity Laboratory Mission (IML-2) which flew on the Space Shuttle in July 1994, provides an outstanding example of NASA's growing experience conducting the kind of research planned for the international Space Sta-

tion. Two hundred scientists representing six different national space agencies cooperated on a series of 80 flight experiments. The mission involved intense international cooperation and allowed some scientists to operate their experiments from the ground by remote control (a process called *telescience*). During this 16-day mission, 25,837 commands were sent from the ground to automatic facilities on the Spacelab, making this the most important demonstration to date of telescience in preparation for the international Space Station. Both in its international character and in its exploitation of the potential of "telescience," this flawlessly executed mission is an important precursor mission for Station research.

QUESTION 3: Are the Space Station Instruments evolving from Spacelab instruments?

Answer 3: NASA is applying scientific and engineering knowledge and experience gained through the Spacelab program as it designs instruments and facilities for the international Space Station. The major Station facilities represent new designs, build on our past experience, and offer significantly improved performance for investigators. In addition, the facilities are composed of modular, standardized racks so that facilities can continue to evolve to include new instruments for investigations as needed.

Each of the facilities has recently undergone a rigorous engineering review conducted by NASA's chief engineer. These reviews ensure that designs fully reflect knowledge gained from NASA's Spacelab experience.

In addition, some science payloads that currently fly on the Space Shuttle will be adapted for long duration on the international Space Station using the EXPRESS rack. The EXPRESS Rack provides a tremendous amount of flexibility for small science payloads to be manifested quickly and deployed on the Station.

QUESTION 4: Historically, the Space Station has been criticized by segments of the scientific community who believe that it has little or no scientific benefit. How do you respond to such criticism? What efforts is NASA making to convince the broader scientific community of the importance of the Space Station?

Answer 4: Demand for orbital research opportunities of the kind provided by the international Space Station exceeds the available opportunities by a large margin. Historically, NASA's resources have allowed the agency to accept approximately the top 20 percent of proposals it receives for this research. This fraction is comparable with the level of selectivity exercised by other major federal science agencies such as the National Institutes of Health and the National Science Foundation. In 1993 and 1994, NASA's Office of Life and Microgravity Sciences and Applications (OLMSA) received over 1,400 new research proposals. The products of orbital research are having a significant impact on their respective disciplines. In 1994, OLMSA's research community produced over 800 articles in peer-reviewed journals. More than 200 scientists from six international space agencies developed over 80 investigations for the second flight of NASA's International Microgravity Laboratory (IML-2) Spacelab mission in July 1994, with results now appearing in peer-reviewed journals. The examples listed in the response to Question 5, below, attest to the inherent scientific value of the output of our research programs.

As orbital research has matured, results from NASA's orbital research program have begun to make important contributions in disciplines ranging from materials sciences to neuroscience. As a result, support in the scientific community has grown rapidly.

- The Federation of American Societies for Experimental Biology FY 1996 Consensus Conference report recommends a budget increase for NASA Life Sciences.
- At the recent 25th International Symposium on Combustion, the most important meeting of combustion scientists in the world, nearly ten percent of the papers presented involved microgravity combustion research. Clearly, microgravity research in combustion science is entering the mainstream.
- Beginning in 1994, the Society for In-Vitro Biology hosts an annual workshop on culturing cells in NASA bioreactors. Interest in the bioreactors has resulted in a full "in depth" session for 1995 to be chaired by Dr. J.M. Jessup of Harvard University/New England Deaconess Hospital and Dr. N.R. Pellis of the Biotechnology Program NASNJohnson Space Center (JSC).
- Since 1992, NASA has signed 18 different cooperative agreements with the National Institutes of Health (NIH). This is one very large scientific community that has become convinced of the value of international Space Station research.
- The National Academy of Sciences has repeatedly expressed its support for international Space Station research through reports of the National Research Council. Most recently, the National Research Council released a report entitled *Microgravity Research Opportunities for the 1990's* in which it outlines a vigorous program of important microgravity research appropriate for the international Space Station.

• In an unprecedented move, last year the American Medical Association adopted a resolution in support of the international Space Station.
• The Planetary Society now supports the international Space Station.

Broadening Access for the Scientific Community:

NASA is fully committed to its close working relationship with the scientific community and to full access to NASA facilities for the most meritorious scientific research. NASA works with the scientific community through its advisory committees and subcommittees, the National Research Council, and working groups of distinguished scientists. Orbital research is solicited through an open, competitive, rigorously peer-reviewed process to ensure access to NASA facilities for the most meritorious science.

NASA's Office of Life and Microgravity Sciences and Applications has cooperative arrangements for jointly supported research and other activities with the National Institutes of Health, National Science Foundation, Department of Defense, Department of Energy, Department of Commerce (National Oceanographic and Atmospheric Administration), and the U.S. Department of Agriculture.

As part of NASA's 18 cooperative agreements with National Institutes of Health, five institutes are participating in planning for the upcoming Space Shuttle Neurolab mission, scheduled for launch in 1998, which will be dedicated to research on the brain. NASA and NIH are jointly sponsoring a number of small payload flights on the Space Shuttle. We look forward to an expanded and productive partnership for international Space Station research as well.

QUESTION 5: Using specific examples what are some of the most important scientific uses of the Space Station, particularly in microgravity research?

Answer 5: It is extremely difficult for NASA to define the "most important" scientific uses planned for the international Space Station. Science aboard the Station will extend across a diversity of life and physical science disciplines and will be important not only for addressing key scientific questions in these disciplines, but also for supporting the long-term exploration and development of space. Another measure of the importance of this research is its contribution as an investment in America's economic future, and its contribution as an inspirational tool for encouraging science students back on Earth. The measurable results of these investments often take decades to reach fruition.

Space Shuttle as a Precursor

Most of our experience with research on orbit comes from our program of Space Shuttle research. The Space Shuttle is currently the world's most advanced platform for orbital research. It has allowed the scientific community to demonstrate the value and further potential of orbital research in a range of disciplines and helped scientists to shape and identify the key questions and fields of research which can only be pursued on orbit. While the Space Shuttle is well suited to this mission of exploring the potential of orbital research, it suffers from some significant limitations for pursuing the potential across science disciplines, particularly with respect to length of research time on orbit. The Shuttle provides only limited access to orbit, with a maximum duration per mission of about 16 days. Within a few months after it is completed, the international Space Station will have provided more time on orbit for American researchers than has been available over the preceding three decades of space research. Extended duration on orbit is essential for many areas of research, especially in the life sciences.

While the Space Shuttle has proven invaluable for exploring scientific research on the space frontier, it is simply not capable of taking full advantage of the opportunities it has helped scientists to discover because of the limited time it can spend on orbit. In order to take advantage of this potential, scientists need extended access to research on orbit and the opportunity to conduct multiple trials and adjust experimental protocols on a regular basis. Researchers need access to the next generation of laboratory facilities supported by power, crew, volume, and data handling capabilities over extended durations that the international Space Station can provide.

The following briefly summarizes the international Space Station's science disciplines and includes some illustrative examples of orbital research in each discipline. In addition to these disciplines, the Station will support Earth Observation, High Energy Astrophysics, a variety of commercial research, and engineering research and technology developments.

Overview of Experimental Science for the International Space Station Space Biotechnology: Protein Crystal Growth—By studying protein crystals and protein crystal growth, international Space Station research will enhance our ability to accurately describe proteins, enzymes, and viruses at the molecular level. Research on these fundamental building blocks of life will enable scientists to develop new drugs and

vaccines much more quickly and effectively. NASA researchers have already used Space Shuttle missions to produce protein crystals far superior to any crystals grown on Earth for research into cancer, diabetes, emphysema, parasitic infections, and immune system disorders. The international Space Station will supply researchers with hundreds of new protein structures; it will provide the opportunity to crystallize proteins that require longer growth times and to characterize the structure of the proteins without subjecting them to the damaging effects of the return trip to Earth on the Space Shuttle.

Examples:

Recombinant human Insulin

• In collaboration with Eli Lilly, the Medical Foundation of Buffalo has obtained a highly detailed map of the structure of human insulin-drug complex based on space-grown crystals. They are using this data to design non-toxic drugs that will bind to the insulin and improve treatment for diabetic patients.

Porcine Elastase

• Elastase is a protein which is involved in emphysema. The detailed structure of this protein was obtained using space-grown crystals. Based on this detailed structure, Vertex Pharmaceuticals is designing drugs to improve treatment for emphysema.

HIV

• NASA is supporting the microgravity crystallization of HIV reverse transcriptase which is a critical enzyme for viral replication. It is believed that this research will better define the enzymes structure so that effective pharmaceuticals can be developed to inhibit the HIV virus.

• The structural biology research group at Marshall Space Flight Center, NASA's Center of Excellence in Biotechnology, was first to publish a structure of a major human antibody that recognizes the AIDS virus.

Human Serum Albumin (HSA)

• HSA is a primary binding protein in the blood and is responsible for distributing drugs throughout the body. Eli Lilly is using the structural information obtained from space-grown crystals to design drugs that bind to HSA with strength appropriate to improve drug delivery. The potential impact of this HSA structure on drug design and delivery is significant, in terms of benefit.

Biotechnology: Cell Culture Research: International Space Station researchers will study methods for growing human tissues outside the body (tissue culturing). The Station will give researchers access to the longer growing times these cultures need to develop and will provide researchers with access to a new generation of laboratory facilities for exploring this exciting field. Future research may lead to an improved understanding of normal and abnormal (cancerous) tissue development, with important implications for the development of new drug therapies and applications for transplant research.

Examples:

Because of limited flight opportunities, examples of recent cell culture research are primarily drawn from ground-based research; however international Space Station research in this field is expected to build upon and extend these results.

• Scientists have applied NASA cell culturing technology to achieve: the first 80-day lung culture, the first normal human intestine culture, and major breakthroughs in the quality of cancer tumor cultures with important implications for cancer research.

• Dr. Jeanne Becker of the University of South Florida has achieved a breakthrough in cell culturing by adapting NASA bioreactor technology to culture ovarian cancer cells into a specimen that eventually resembles the tumor from which they were harvested.

• Dr. Josh Zimmerberg of NIH's National Institute for Child Health and Human Development is using NASA-funded bioreactors and NASA-funded resident technical staff to pursue AIDS research goals under a 1994-1998 NASA-NIH joint venture.

• Dr. Lisa Freed of the Massachusetts Institute of Technology is using the NASA bioreactor to propagate cartilage cells to engineer three-dimensional cartilage tissue. Her work has enhanced our understanding of tissue development and shows a clear prospect for using microgravity to produce models and transplantable cartilage tissues that will revolutionize our approach to joint disease and injuries.

Combustion Science: Scientists use microgravity to simplify the study of complex combustion (burning) processes. Since combustion produces over 85 percent of Earth's energy, even small improvements in efficiency would have large environmental and economic benefits. In addition, an improved understanding of combustion may improve processes for producing advanced materials such as carbon fibers for composites and fullerenes for a variety of electronic applications as the products of combustion. The international Space Station will allow scientists to manipulate

a wider variety of variables and repeat and modify experiments to understand issues concerning the dynamics of combustion that cannot be studied on Earth.

Examples:

• Combustion science researchers using NASA Lewis Research Center facilities have applied for a patent on a device for stabilizing fuel-lean flames and reducing NO_x (oxides of nitrogen), a major source of air pollution.

• NASA investigators have obtained and analyzed the first data on Burke-Schumann gas jet diffusion flames (a classical flame configuration treated in virtually all combustion textbooks). These data represent the first verification of this theory available since its original development in 1928.

• NASA investigators have collected the first data on soot production in microgravity diffusion flames. The understanding which will be obtained from these studies has great potential practical benefits in designing combustors for industrial use and in many manufacturing processes that use combustion such as carbon-black and carbon-fiber matrix production.

• At the recent 25th International Symposium on Combustion, the most important meeting of combustion scientists in the world, nearly ten percent of the papers presented involved microgravity combustion research.

Materials Science: Researchers use low gravity to advance our understanding of the relationships between the structure, processing, and properties of materials. Findings in materials science have very broad applicability to industrial processes, including the production of semiconductors, glasses, metals, alloys, polymers, and ceramics. The international Space Station will give researchers access to the variety of furnaces and other facilities they need to conduct this important research over long durations and through repeated trials. The Station will provide researchers with the capability, critical in this field, to modify experimental protocols and explore a variety of experimental parameters (e.g., rate of heating and cooling, make up of samples, etc.) on extended orbit.

Examples:

• Dr. Martin Glicksman's (Rensselaer Polytechnic Institute) experiments aboard the Space Shuttle's second United States Microgravity Payload (USMP-2) produced groundbreaking new insights into how the structure of metal forms. These observations will aid in the development of stronger or more corrosion-resistant metal alloys.

• Based on his orbital research, Dr. Julian Szekely, of the Massachusetts Institute of Technology, developed new mathematical techniques to model the behavior of melted metals. These techniques have been used by the metals and semiconductor industries to design equipment and to predict important materials processing parameters which may lead to improved manufacturing processes.

• Space experiments have demonstrated that when gravity's effects are substantially reduced, other forces (such as surface tension) can predominate. Experiments have shown that these secondary forces are more significant than previously thought, affecting many ground-based materials production techniques in unexpected ways and opening the door for further study and improved processes and materials for the future.

Fluid Physics: Researchers use low gravity to study the properties and behavior of fluids (liquids, gases, and mixtures). Fundamental knowledge of fluid behavior is essential to industrial activities ranging from energy production to materials engineering. In addition to its advanced facilities for studying fluid physics, the international Space Station will serve as an engineering testbed.

Examples:

• The NASA microgravity program has had a qentral role in stimulating new understanding of the ways in which heat and chemical species are transported in semiconductor crystal growth, metals processing, separation of biological molecules, and protein crystal growth.

• Experiments on a 1995 Spacelab flight used a physical model of the atmosphere to provided unexpected evidence of fluid instabilities previously unpredicted by existing atmospheric computer models.

Microgravity Physics: Scientists use microgravity to test fundamental theories of physics with degrees of accuracy that far exceed the capacity of Earthbound science. Physics in microgravity sheds light on changes in the state of matter including those changes responsible for high-temperature superconductivity. Many of these experiments require the extended access to low gravity that only the international Space Station can supply in order to observe equilibria as they develop over time.

Examples:

• Data from NASA critical point experiments is being used to develop theories in a field known as dynamic cooperative phenomena. This field studies the behavior

of large numbers of interacting dynamic elements and has applications in areas as diverse as polymer science, atmospheric turbulence, and population dynamics.

• In 1992, an orbital research experiment produced observations that tested renormalization theory with a degree of precision five times greater than any experiment conducted on Earth. Renormalization theory is a Nobel prize winning physics theory with applications to particle physics and superconductivity.

Gravitational Biology: Scientists study gravity's influence on the development, growth, and internal processes of plants and animals. Their results expand fundamental knowledge that may benefit medical, agricultural, and other industries. In addition to the advanced facilities and resources supplied by the international Space Station, this field requires extended duration research to fully explore the effects of microgravity over the long time periods required for embryos to develop and over multiple generations of plants and animals.

Examples:

• Orbital research has demonstrated that gravity exerts an influence on cell growth, especially in plants and in unicellular organisms, on chromosomal aberration and on the process of reproductory cell formation.

• Space radiation research results improve our understanding of ionizing radiation damage to cells and organs, provide information on the ability of cells to repair themselves, and aid in the discovery of improved protection against the effects of radiation exposure.

• NASA plant research has elucidated the critical role played by calcium in translating physical phenomena into chemical signals in plants.

• Orbital research has invalidated theories that seek to explain the movements of some plants as they grow. Existing theones relied upon gravitational force to explain certain movements and were found to be invalid when tested in the low-gravity environment of space.

• NASA-supported research by Dr. Donald Ingber (Harvard Medical School) has made a significant contribution to cell research by describing how a force stimulus acting on a cell is translated into a chemical change within the cell.

His work on models of cell structure has been published in *Science, The Journal of Cell Science, and Cell Biology.*

Space Physiology: Space research provides unique insights into how the heart and lungs function; the growth and maintenance of muscle and bone; perception, cognition, posture, and balance (neuroscience); and the regulation of the body's many systems (regulatory physiology). Advances in space physiology are essential for expanding human presence in space and, at the same time, they support breakthroughs in understanding and treating medical problems back on Earth. Many of the key questions in this field cannot be fully explored through the short-duration experiments available on the Space Shuttle. The international Space Station will supply the needed long duration and access to a centrifuge for creating variable force levels that are essential for exploring the key questions in this field.

Examples:

Space Physiology: Regulatory Physiology and Function of Heart and Lungs Scientists will use the low-gravity environment of the international Space Station over long durations to produce new insights into the function of the body's systems for regulating the flow of blood and other fluids.

• Space research has identified the existence of previously unknown regulatory processes that control blood volume and constituents—processes that are vital for patients in grave shock, trauma, after surgery, or suffering from systemic diseases.

• Space research shows that blood pressure sensors in arteries to the brain lose some of their ability to regulate blood pressure during space flight. Similar abnormalities are observed in patients who have had heart attacks.

• Space research has shown that the heart can increase the amount of blood pumped (cardiac output) under conditions previously thought to decrease the amount of blood pumped. This will lead to new understanding about heart function.

• Space research has indicated that the differences present on Earth between blood flow to the highest and lowest segments of the lungs persist in space, contrary to current theories in the textbooks. Thus, many diagnostic and therapeutic measures rely on concepts that are now shown to be inadequate in relation to the overall functioning of a human lung.

Space Physiology: Research on Muscle and Bone

Because of the very low levels of gravity experienced in Earth orbit, otherwise healthy young astronauts experience rapid bone demineralization that is comparable to osteoporosis progressing at an accelerated rate. International Space Station research will allow for the full exploration of these phenomena over long periods.

• Orbital research has shown that changes in hormones do not completely explain the rapid loss of calcium from bones during spaceflight. Researchers must identify

mechanical, gravity-dependent processes. These findings may lead to new concepts in the diagnostics and therapy of skeletal disorders.

• Fundamental research by Dr. Richard Grindeland (Ames Research Center) in collaboration with Dr. Reggie Edgerton (University of California, Los Angeles), and investigators at Genentech, Inc., has shown that exercise, coupled with administration of doses of growth hormones that by themselves had no effect, prevented muscle atrophy. This approach opens up a new therapeutic avenue for rehabilitation as well as for preventing some of the effects of aging.

• Experiments being solicited cooperatively with the National Institute for Arthritis and Musculoskelatal and Skin Diseases for upcoming flights will enhance researchers' insight into the cellular mechanisms of bone mineral loss and may allow them to develop drugs or other treatments that target the specific causes of bone mineral loss.

• Space life sciences researchers have developed a theory of the remodeling of bone that accounts for the effects of all of the stresses on bone imposed during daily activity. In addition to stimulating new avenues of basic research, the model has been applied by others to the evaluation of orthopedic implant designs, the influence of exercise on bone density, and to age-associated bone mineral loss.

Space Physiology: Neurosclence

The body senses gravity directly by receptors in the vestibular organs in the ears (balance system) and indirectly by other specialized receptors. Space is the only environment in which gravity's effect on these receptors disappear in a healthy individual. The international Space Station offers a unique opportunity for basic neurosensory research to develop insights into the functions of the central nervous system.

• NASA research on the balance system has resulted in new discoveries on the organization of sensory neurons and the nervous system's capacity to adapt to new sensory environments.

• NASA research on the balance system has overturned a 50-year-old concept of gravity sensor organization. This work also begins to illuminate differences in function between the two kinds of detector cells known to provide our sense of balance.

• Space research has invalidated the text-book theory behind a test of inner ear function (caloric nystagmus testing) that is practiced world-wide every day. Improved understanding of this test could lead to improved diagnosis for thousands of patients.

• Because the basic organization of the gravity sensors is similar to that found in the retina and parts of the brain and nervous system, this research has great potential for helping researchers understand the basis for learning and memory.

• NASA research on the organization of sensory neurons could make contributions in the world of advanced computer design and artificial intelligence.

• NASA makes several specialized facilities supporting neuroscience research available to scientific researchers of other agencies, including NIH, the Department of Agriculture, and the Department of Defense.

QUESTION 6: The centrifuge is said to be critical to life sciences research on the Space Station but is not deployed until the year 2004 [sic]. Does that mean that this type of research cannot be conducted until that time?

Answer 6: The launch date for the international Space Station centrifuge is now in 2001, not 2004 as supported by NASA's FY 1996 budget request. NASA has accelerated development of the centrifuge, modified its design approach, and produced savings of over $114 million in development costs while at the same time adding a new piece of equipment, the life sciences glovebox. NASA has established a two-phase program that provides a four-arm centrifuge capability in 2001 and adds four more arms to create an eight-arm centrifuge by 2003. NASA has maintained centrifuge performance requirements including the centrifuge diameter (2.5 meters), vibration level, and vanabl? force (0-2g) capabilities.

Beyond the centrifuge itself, the centrifuge facility includes the following supporting equipment for handling, supporting and caring for plants, animals, and samples:

habitat holding units (2 racks)
plant & rodent habitats
life sciences glovebox

The glovebox, habitats, and one holding rack will be delivered in 2001 with the second holding rack following in 2003.

Over the long term, the centrifuge facility is critical to life sciences research because it will allow scientists to conduct controlled, long-duration experiments in mammals and plants and to investigate the effects of gravity at levels ranging from zero to two times the force of gravity on Earth. However, life sciences research in low gravity is still a new, wide-open field of scientific research, and there are a wide variety of important investigations that will be conducted before the centrifuge facil-

ity is available. Prior to the centrifuge facility becoming available in 2001, research will focus on cell and molecular biology and research on the human adaptation to long-duration spaceflight. Researchers will have access to the first rack of the Gravitational Biology Facility and one rack of the Human Research Facility to conduct this important life sciences research before the centrifuge facility is available.

QUESTION 7: How will the changes in the NASA organization resulting from the zero-base review affect the Office of Life and Microgravity Sciences and Applications?

Answer 7:

Institutes

The Zero Base Review and specifically the Science Cross Cut Team recommends that NASA establish Science Institutes at the following field centers: Biomedical Institute at the Johnson Space Center (JSC), Astrobiology Institute at the Ames Research Center (ARC), Combustion and Fluids Institute at the Lewis Research Center (LeRC) and the Biotechnology and Materials Science Institute at the Marshall Space Flight Center (MSFC).

NASA is establishing an Institute Framing Committee to define the contents and implementation of the Institutes over the next several months. In general, NASA Science Institutes would be privatized arrangements in which government-owned assets could be managed by an external entity, such as a university or company, or a consortium of these.

By creating the Science Institutes, NASA seeks to enhance the quality of NASA science. Organizing NASA science through institutes is not a budget-cutting measure; rather, this initiative is designed to strengthen NASA's science program. NASA currently anticipates no net savings from this new approach.

At this time, NASA envisions the Biomedical Institute at JSC to be the first Institute established. NASA may use the Biomedical Institute as a model for the others.

Headquarters

The Zero Base Review recommended that each NASA Headquarters organization will be required to reduce its current staff level by 40 percent by 1999. OLMSA will reduce its staffing from 78 to 48 by 1999, and this new staffing level will drive changes in the way in which OLMSA manages its programs. OLMSA will continue to define programs, perform some budget functions and manage the peer-review program. Other program management responsibilities will be transferred to the NASA centers, and the centers will be responsible for implementation and administration of programs.

NASA Headquarters will be managed by Enterprises; OLMSA and the Office of Space Flight co-manage the Human Exploration and Development of Space (HEDS) Enterprise. While the two offices will retain separate budgets, management by enterprise may require that OLMSA change the structure of its budget.

The Zero Base Review recommends that NASA implement an agency-wide system of full program accounting and costing. Under the new system, NASA Centers will charge responsible offices for the full costs of implementing their programs. Of all of the recommendations of the Zero Base Review, the full program accounting and costing recommendation could have the biggest impact on how the centers manage their resources; thus it could become one of the most important changes to program implementation. A team has been appointed to review this recommendation of the Zero Base Review to determine appropriate implementation strategies and schedules.

Program Reductions

As part of the Zero Base Review process, each center conducted a selfassessment of its work force and infrastructure (as defined by the agency) and identified a level of savings based on efficiencies and restructuring. These proposed reductions will be reviewed this summer to ensure there is no impact to science or the international Space Station.

○

ISBN 0-16-047727-1